(2)

ELF Communications System Ecological Monitoring Program: Electromagnetic Field Measurements and Engineering Support--1991

D. P. Haradem
J. R. Gauger
J. E. Zapotosky

Technical Report D06200-4
Contract No. N00039-88-C-0065
December 1992

Prepared for:

Communications Systems Project Office
Space and Naval Warfare Systems Command
Washington, D.C. 20363-5100

Submitted by:

IIT Research Institute
10 West 35th Street
Chicago, Illinois 60616-3799

Printed in the United States of America

This report is available from:

National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	December 1992	Technical; 1983 to 1991

4. TITLE AND SUBTITLE

ELF Communications System Ecological Monitoring Program: Electromagnetic Field Measurements and Engineering Support--1991

5. FUNDING NUMBERS

6. AUTHOR(S)

D. P. Haradem, J. R. Gauger, J. E. Zapotosky

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

IIT Research Institute
10 West 35th Street
Chicago, Illinois 60616-3799

8. PERFORMING ORGANIZATION REPORT NUMBER

D06200-4

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Space and Naval Warfare Systems Command
Washington, D.C. 20363-5100

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

The ELF Communications System enables the U.S. Navy to communicate with submarines worldwide at operational depth and speed. The system consists of transmitting facilities in Wisconsin and Michigan that synchronously broadcast messages. Transmitters became fully operational in Wisconsin in 1985 and in Michigan in 1989.

In situ studies to monitor for possible bioelectromagnetic effects from operation of both transmitters were initiated in 1982. The studies use a split-plot or blocked strategy to examine differences in space (treatment/control sites) or time (preoperational/operational). Physiological, developmental, behavioral, and ecological variables for dominant biota in upland, wetland, and riverine habitats near the ELF System have been examined in these studies. In Wisconsin, data collection for all studies was completed by the end of 1989; in Michigan, studies continued during 1991. It is anticipated that data collection will continue at Michigan study sites through 1993.

In support of this research, IIT Research Institute annually documents the ambient ELF electromagnetic (EM) environment, including EM fields produced by both the ELF System and electric power distribution (60 Hz). This report documents ELF EM field intensities at all study sites active in 1991, and is comprehensive for the period 1983-1991. Other engineering activities performed during 1991 in support of the ecological studies are also described.

14. SUBJECT TERMS

Extremely Low Frequency	Ecology
Electromagnetic Fields	ELF Communications System
Environmental Studies	ELF Ecological Program

15. NUMBER OF PAGES 312

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unlimited

FOREWORD

This report documents measurements of extremely low frequency (ELF) electromagnetic (EM) fields made in support of the U.S. Navy's ELF Communications System Ecological Monitoring Program from 1983 through 1991. The report also describes other engineering activities performed in support of the Program during 1991. This work was funded by the Space and Naval Warfare Systems Command, Submarine Communications Project Office, under Contracts N00039-81-C-0357, N00039-84-C-0070, and N00039-88-C-0065 to IIT Research Institute (IITRI). IITRI measurement personnel during 1991 were Messrs. D. P. Haradem, J. R. Gauger, H. C. Coron, P. J. Coron, R. G. Drexler, F. T. Metzger, and D. J. Vallier and Dr. J. E. Zapotosky.

Respectfully submitted,
IIT RESEARCH INSTITUTE

D. P. Haradem
Research Engineer

J. R. Gauger
Engineering Advisor

J. E. Zapotosky, Ph.D.
Science Advisor

Approved:

R. D. Carlson
Program Manager

CONTENTS

CONTENTS (continued)

FIGURES

FIGURES (continued)

TABLES

ELF COMMUNICATIONS SYSTEM ECOLOGICAL MONITORING PROGRAM: ELECTROMAGNETIC FIELD MEASUREMENTS AND ENGINEERING SUPPORT--1991

1. INTRODUCTION

1.1 Ecological Monitoring Program

In 1981, concurrent with its decision to complete construction of an Extremely Low Frequency (ELF) Communications System, the Department of the Navy established an Ecological Monitoring Program. The purpose of the program is to determine whether long-term exposure to electromagnetic (EM) fields produced by the communications system will result in adverse effects on resident biota or their interrelationships. Monitoring studies are being performed by investigators from several universities, and their efforts are being supported by IIT Research Institute (IITRI).

IITRI assists the investigators by making EM field measurements and providing other engineering support. EM field measurements are needed to ensure significant differences in EM exposure between paired study sites and to provide data that may be needed for further examination of possible cause-and-effect relationships. Engineering support provided by IITRI includes design, fabrication, and installation of EM control and recording equipment for *in situ* culture chambers; mitigation of EM exposures in laboratories; and mitigation of on-site ambient monitoring equipment with respect to EM safety, EM interference, and damage from nearby lightning strikes. IITRI personnel also summarize data on the operational characteristics of the ELF transmitters, and review the use of EM data in reports by investigators. All of these support activities are documented annually in IITRI technical reports.

This report documents engineering support activities during 1991 and provides a comprehensive summary (1983-1991) of EM exposures at study sites and laboratories that were still active in 1991. Documentation of EM field measurements and engineering support for completed studies--namely, the wetlands, slime mold, and bird species and communities studies performed in Wisconsin--appears in previous annual reports.[1-7] Final reports for the Wisconsin studies have also been published.[8-10]

1.2 ELF Communications System

The ELF Communications System includes two transmitting facilities, one located in the Chequamegon National Forest in Wisconsin and the other in the Copper Country and Escanaba River State Forests in Michigan (see Figure 1). Each facility consists of a transmitter connected to long overhead wires (antennas) with buried ground terminals at their ends. Both the antenna and grounding elements are located in cleared rights-of-way (ROW). The Naval Radio Transmitting Facility-Clam Lake, Wisconsin (NRTF-Clam Lake) has a north-south (NS) and an east-west (EW) antenna, each 14 miles long. The Naval Radio Transmitting Facility-Republic, Michigan (NRTF-Republic) has a 28-mile-long NS antenna and an

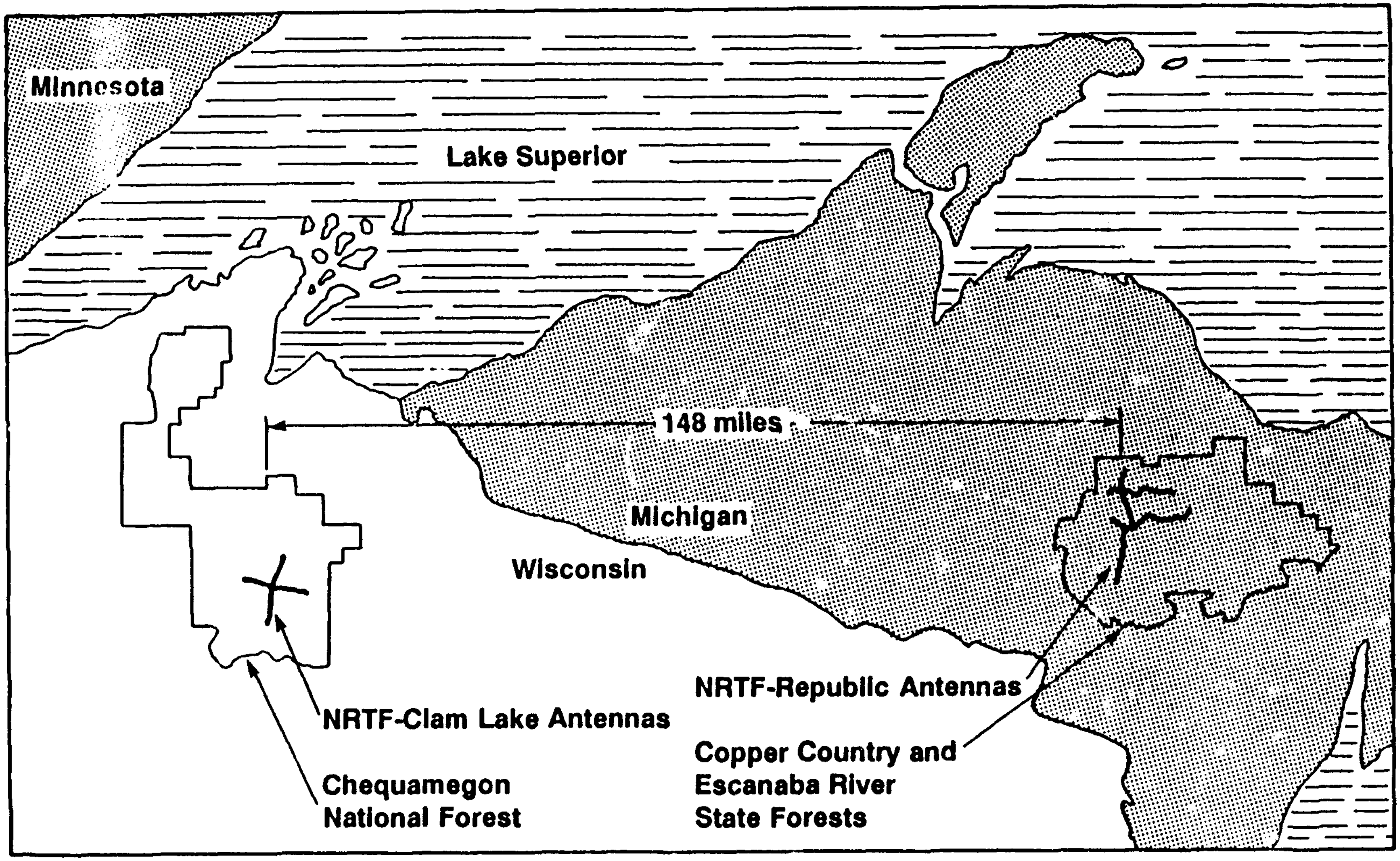


FIGURE 1. ELF COMMUNICATIONS FACILITIES IN WISCONSIN AND MICHIGAN.

EW antenna comprised of a northern east-west (NEW) and a southern east-west (SEW) element, each of which is approximately 14 miles long. The end of each antenna or antenna element terminates in one to three miles of buried horizontal ground wire and one or more arrays of vertical electrodes 100 to 300 feet deep.

The transmitters broadcast messages using ELF EM fields; these fields are the operational component to be evaluated by the Ecological Monitoring Program. The EM fields produced by the ELF Communications System are:

- a magnetic field, essentially the same in the air and the earth, that is generated by the electrical current in the antenna elements and ground terminals
- an electric field in the earth that is the sum of the fields induced by the magnetic field and the current flowing from the buried ground terminals
- an electric field in air that is produced as a result of the difference in potential between the antenna element and the earth or created as a by-product of the earth electric field.

The frequency produced by an operational ELF Communications System is modulated using minimum shift keying (MSK), a special form of frequency shift keying. An important aspect of MSK modulation is that minimal energy is generated outside the signal bandwidth. The transmitted message is binary coded: If a zero is to be transmitted, the frequency of the current is 72 Hz; for a one, the frequency is 80 Hz. The center frequency is therefore 76 Hz, and is the frequency with the greatest power spectral density. The planned frequencies for routine operation of the ELF Communications System are modulated between 72 and 80 Hz; in addition, the system can transmit at frequencies between 40 and 48 Hz (44 Hz center frequency). Figure 2 illustrates an MSK waveform and its corresponding binary code and power spectral distribution.

Exposure of resident biota to 76 and 44 Hz EM fields has been quite variable over the development of the ELF Communications System. In order to address these differences, some ecological investigators have divided EM exposure into preoperational, transitional, and operational periods. During the pre-operational phase, biota received no EM exposure from the ELF system. The transitional phase began with the intermittent energizing of transmitters for testing, most often at intensities lower than those of a fully operational ELF system. During the operational phase of the ELF system, EM exposures are nearly continuous and at planned, full-power intensities. The NRTF-Clam Lake was first energized in 1969 and became fully operational during the last quarter of 1985; the NRTF-Republic was first energized in early 1986 and became fully operational during the last quarter of 1989.

1.3 Paired-Site Concept

In order to examine for possible effects, the monitoring program employs a split-plot design that compares data collected at a control site with data collected at a treatment site. The paired sites have

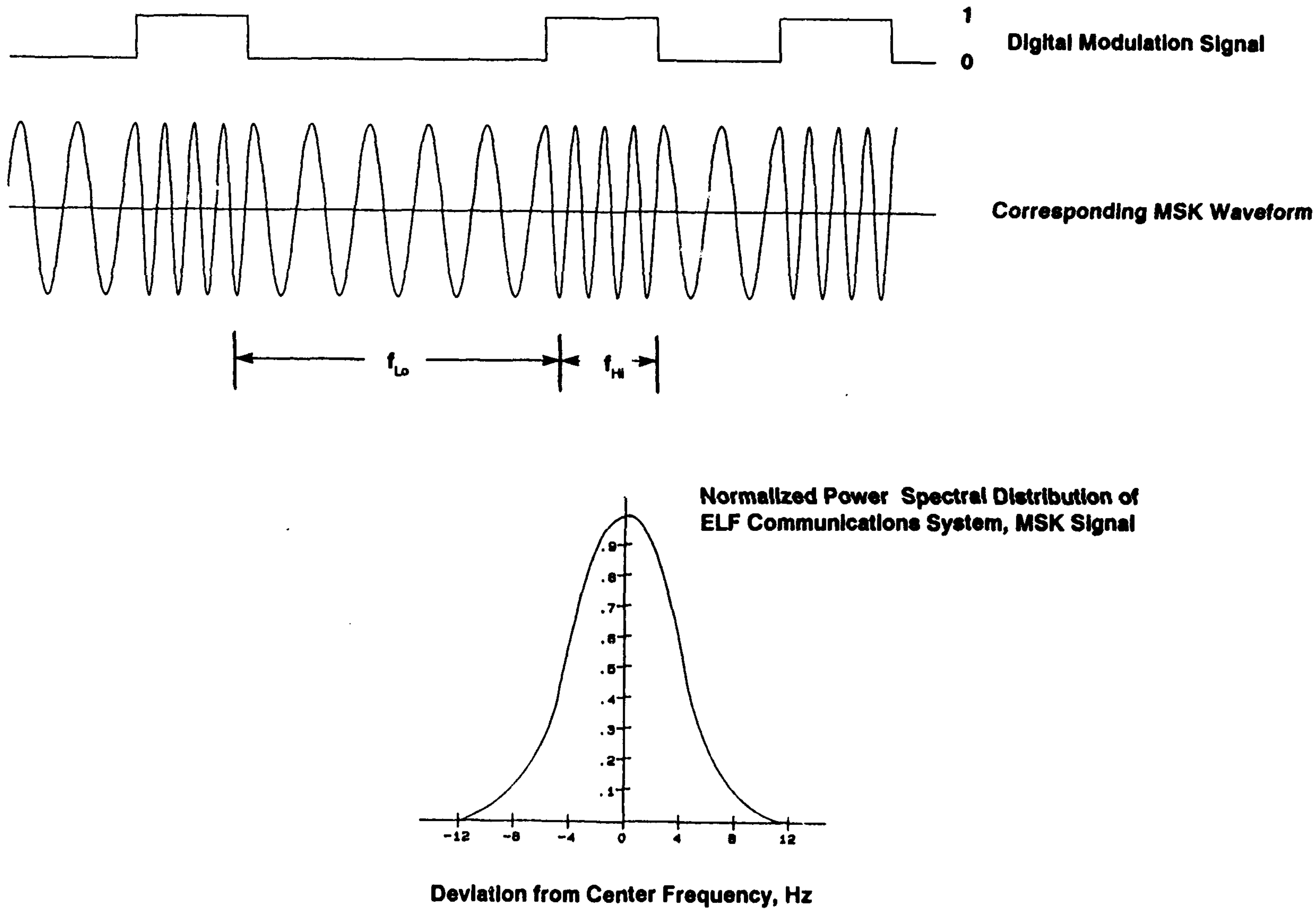


FIGURE 2. MSK WAVEFORM AND POWER SPECTRAL DISTRIBUTION.

matched biotic and environmental factors, but have purposely dissimilar 76 Hz EM exposures. The control site is used to measure the effects of environmental factors on study variables. Variables at the treatment site reflect the effects of environmental factors as well as possible effects from exposure to higher 76 Hz EM fields.

Dissimilar 76 Hz EM exposures were attained by situating treatment sites relatively close to the ELF Communications System while placing control sites at a greater distance. The EM exposure criteria used in site selection are expressed in equation form as follows:

$$T_{(76\ \mathrm{Hz})}/C_{(76\ \mathrm{Hz})} > 10 \tag{1}$$

$$T_{(76\ \mathrm{Hz})}/T_{(60\ \mathrm{Hz})} > 10 \tag{2}$$

$$T_{(76\ \mathrm{Hz})}/C_{(60\ \mathrm{Hz})} > 10 \tag{3}$$

$$0.1 < T_{(60\ \mathrm{Hz})}/C_{(60\ \mathrm{Hz})} < 10 \tag{4}$$

where $T_{(76\ \mathrm{Hz})}$ = treatment site exposure due to ELF Communications System
$T_{(60\ \mathrm{Hz})}$ = treatment site exposure due to power lines
$C_{(76\ \mathrm{Hz})}$ = control site exposure due to ELF Communications System
$C_{(60\ \mathrm{Hz})}$ = control site exposure due to power lines

By means of these criteria, the monitoring program sought to ensure that the intensities of the 76 Hz EM fields at treatment sites were significantly greater than those at control sites (Equation 1); that the 76 Hz EM field intensities at treatment sites were significantly greater than the 60 Hz EM field intensities at both treatment sites (Equation 2) and control sites (Equation 3); and that there was minimal difference in 60 Hz EM fields between treatment and control sites (Equation 4).

Nearly all site pairs met or exceeded the EM exposure criteria. In a few exceptional cases, pairs came close, but failed to meet all the criteria. Because the sites in question could not be relocated without adversely impacting matched biotic considerations, they were accepted.

At the NRTF-Republic, temporal comparisons between the preoperational and operational phases of the ELF Communications System are possible, in addition to the spatial comparisons of treatment and control sites. Study investigators have collected their preoperational data and are now in the operational phase of their studies. Only spatial comparisons were made at the NRTF-Clam Lake, because the transmitter has been operating since 1969 and no preoperational data base existed.

1.4 Annual Measurements of EM Fields

IITRI performs an annual survey to measure the EM fields at each study site. Annual measurements of 60 Hz and 76 Hz EM fields are required in order to document changes in EM exposure at study sites from year to year. Ambient 60 Hz EM fields have changed due to the construction of new power lines, variations in the local use of electric power, and the presence of the ELF antennas themselves, which have been shown to couple and reradiate 60 Hz EM fields. The 76 Hz EM field intensities produced by the ELF Communications System have changed because of reconfiguration of antenna elements and because of operation at different antenna currents. In 1989 and thereafter, 76 Hz EM exposures were also influenced by the simultaneous operation of both antennas, a system configuration not present in prior years.

Other EM aspects that have been examined during the annual surveys include:

- 60 Hz and 76 Hz harmonics
- EM field levels produced at Michigan study sites due to the operation of the NRTF-Clam Lake
- EM field values as a function of the phase angle between antennas.

The first two aspects were examined and found to be below detection levels or so low that they are not considered to be a confounder in treatment-versus-control comparisons. The third aspect--the effect of the antenna phase angle on EM exposures--was examined in Wisconsin only. This aspect is of concern for sites close to multiple antenna elements, and usually affects only the earth electric field. Phase measurements at the NRTF-Clam Lake are treated in previous annual reports.[3-7] Results showed that the effect of antenna phase angle on the longitudinal electric fields was typically less than 5%. The effect of the antenna phase angle on EM exposure is of concern at only one Michigan study site (site 10T3, bird species and communities studies). This aspect could not be measured because of schedule constraints and the full-time NPTF-Republic operating schedule, but it is expected to be similar to that in Wisconsin.

1.5 1991 Engineering Support

IITRI has provided a variety of engineering support in response to specific needs of individual researchers. These support activities are summarized here; details appear in Sections 2 and 4.

The soil amoeba studies use buried growth chambers that isolate study organisms from the surrounding soil. IITRI personnel reviewed the proposed design of the chambers in 1983, and found two areas of concern to be the matching of internal to external EM fields and the measurement of internal EM fields. IITRI subsequently designed and fabricated chamber exposure control apparatus to address the field-matching problem, and assisted the study investigator with field setup and installation. In 1988, IITRI fabricated and installed improved exposure control equipment and also designed and fabricated microprocessor-controlled data loggers and installed them at each study site. The data loggers make

hourly measurements of the voltage and current of each chamber, the earth electric fields at each site, and the temperatures in the soil and partially buried data logger housings. The data logger monitoring provides documentation of any variations in either the electric fields or current densities of the growth chambers that might result from factors such as rainfall, changes in temperature, or changes in the conductivity of the chamber growth medium. Monitoring of these chambers continued throughout the 1991 field season. Cumulative plots of all data logger field measurements made at the soil amoeba antenna and ground study sites through 1991 are presented in Appendix F.

In 1991, the principal investigator for the soil arthropods and earthworms study proposed the use of a buried chamber to isolate earthworms for controlled reproduction studies. IITRI assisted in the design of the chamber--a mesh nylon bag (incubation bag), which allows current flow across the interface while prohibiting the movement of worms into or out of the bag. EM field intensities within the incubation bags were characterized. Support was also provided to identify a remote location with a suitable EM field environment for collection of worms to be used in the study to site the burial locations for the bags at the study sites, and to conduct long-term monitoring of electric fields within the bags.

Electric field monitoring at the soil arthropods and earthworms study sites was accomplished using data logger monitoring systems similar to those installed at the soil amoeba study sites. These loggers were configured to monitor the earth electric field intensity both inside and outside the incubation bags and outside the bags at three soil depths corresponding to different soil horizons. Soil temperature at two depths, air temperature, and rainfall were also monitored.

Researchers for the upland flora and soil microflora studies requested a more detailed characterization of the EM field variation across their treatment sites in order to test for a correlation between EM field exposures and aspen growth rates. Measurement points were added at the antenna and ground study sites in 1989 to define EM field profiles, which could then be used to estimate EM field intensities across the study sites. In 1990, still more detailed characterization of these sites was performed by setting up a grid of electric field measurements that was used to rigorously define electric field contours at the sites. In addition, fixed earth electric field probes were established to determine temporal variations of this field at these sites. Measurements continued to be made twice monthly at the fixed probes during the 1991 field season.

In 1991, temporal variability of the earth electric field at the upland flora study sites was more accurately quantified with data logger monitoring systems. Data loggers were installed at the antenna and ground site pine plantations and in the antenna site hardwood stand. Each logger was configured to monitor the earth electric field at several fixed probes along transects that are perpendicular to the antenna or ground wire, and the air and soil temperature at a single location.

A data logger monitoring system was also installed in 1991 at the aquatic ecosystems treatment study site for continual monitoring of earth electric fields. Earth electric fields at several points in the riverbed are monitored by this logger, as well as the air and riverbed temperatures.

In total, eight data logger monitoring systems were used in 1991 to monitor earth electric fields and weather parameters. A ninth system at the soil amoeba control study site was used to monitor weather parameters only. The data logger measurements have provided information on earth electric field temporal variability. Seasonal and diurnal variations have been examined, as well as special cases of field variability in study chambers, in the riverbed, and in multiple soil horizons. Statistical analyses of the upland flora logger measurements were also made, and measurement averages were used to construct plots of electric field profiles.

In the past the NRTF-Clam Lake and the NRTF-Republic have operated at numerous frequency, modulation, and power conditions in order to accommodate Naval fleet operations, the testing of new hardware, and the testing of utility interference mitigation. IITRI has established and maintains a computer data base of these past preoperational data as well as data on the fully operational periods. Operational summaries are provided, which are intended for use by investigators, in conjunction with annually measured EM field values at the study sites, to construct EM exposure regimes.

2. ECOLOGICAL MONITORING STUDY SITES

Selection of treatment and control sites began in 1983 based on the criteria described in Section 1.3. The sites selected for the Michigan studies are shown in Figure 3. The seven studies are identified in the upper left-hand corner of this figure. Collection sites for red maple leaves and pine needles do not appear in the figure, because they are beyond the range of the map shown.

The study sites in Michigan include those for treatment and control as well as special locations such as laboratories, a holding facility, displacement points, and remote collection sites. The small mammals and nesting birds studies and the native bees studies share a holding facility that is used to house animals in a low-EM field environment near the study laboratories prior to laboratory testing. The small mammals and nesting birds studies also employ sites from which displaced animals are released for timed returns to their capture location. The soil microflora studies and the soil arthropod and earthworms studies make use of remote locations to collect foliage and earthworm samples, which are brought back to the study sites. EM field exposures at all of these special locations are important because they could confound interpretation of data collection at the treatment and control sites. They have, therefore, been included with treatment and control sites in the annual measurement program for Michigan.

Because sites in Michigan were chosen prior to the construction of the NRTF-Republic antennas, their selection was based on measurements of 60 Hz EM fields and preoperational estimates of the 76 Hz EM fields that were prepared using engineering models of the proposed Michigan ELF antennas. The Michigan antennas were completed in 1986, and 76 Hz measurements were then possible for the first time. Measurements made in 1986 verified the acceptability of the Michigan treatment and control sites: all sites were confirmed to be either acceptable or conditionally acceptable, as defined in Appendix H.

The 76 Hz earth electric field intensity ratio (R1) for several aquatic ecosystems site pairs have been low since the start of the site selection process. Nonetheless, the sites were labeled conditionally acceptable because of limitations in the length of the Ford River over which matched habitats could be found and some uncertainty of the 76 Hz field intensities under a fully operational ELF system. In 1989, EM exposure ratios were recalculated using field intensity measurement data from the fully operational ELF system. The R1 ratio continued to be of concern for all aquatic study activities. IITRI made suggestions for site relocations that would improve the intersite exposure ratios. In early 1990, IITRI personnel visited the aquatic ecosystems study sites, along with the study researchers, to discuss the site relocations, measure the EM fields at the new locations, and quantify the new EM exposure ratios.

Site changes for the aquatics study and their effects on exposure ratios are detailed in a previous report.[11] A present overview of all aquatic ecosystem study sites and activities is given in Figure 4. Although new study locations were established to improve treatment/control exposure ratios, study activities are also continuing at original locations to maintain continuity with historical data. EM field ratios were

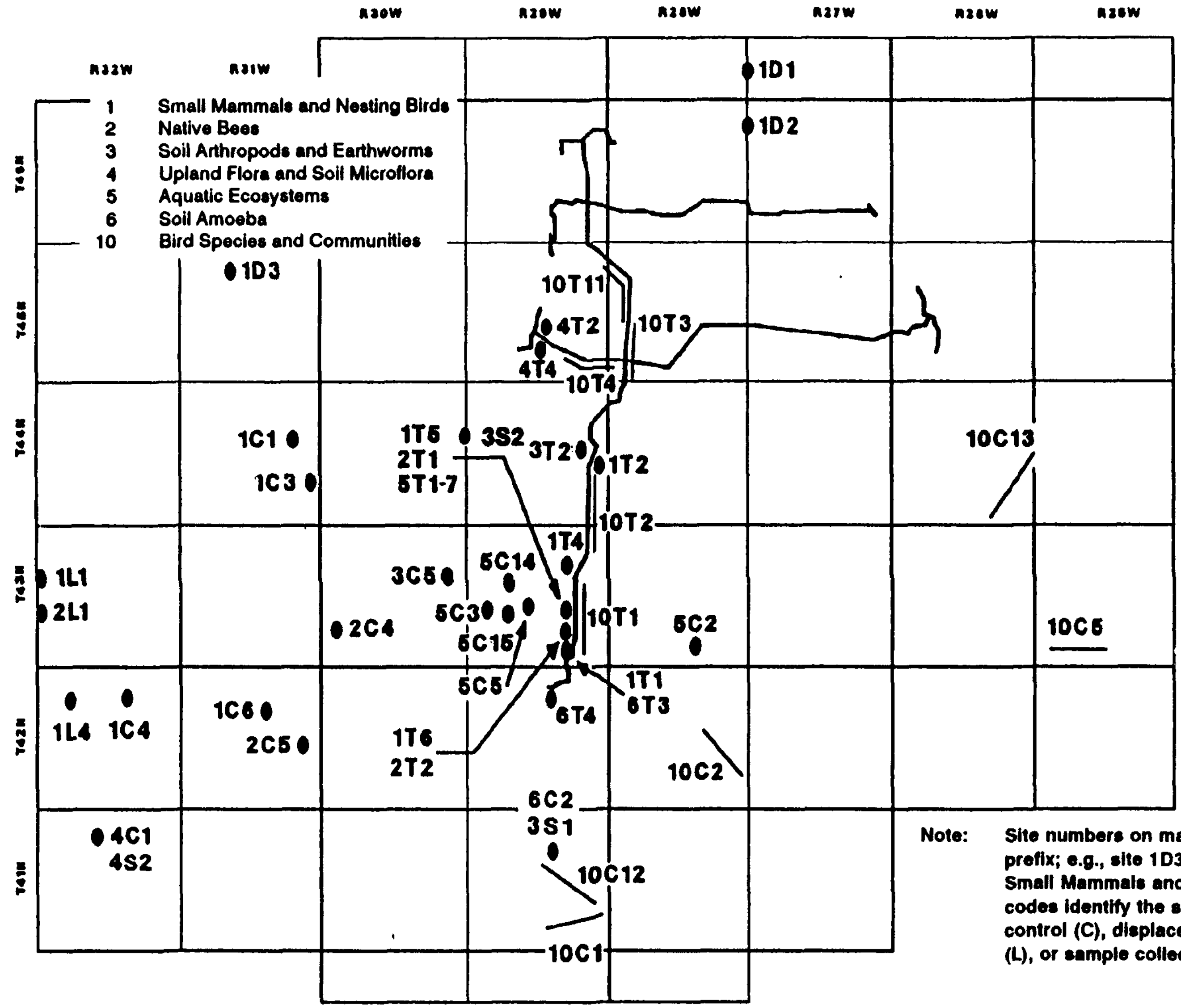


FIGURE 3. FIELD SITES FOR MICHIGAN ECOLOGY STUDIES.

Note: Site numbers on map use study number as prefix; e.g., site 1D3 is part of Study 1, Small Mammals and Nesting Birds. Letter codes identify the site as treatment (T), control (C), displacement (D), laboratory (L), or sample collection (S).

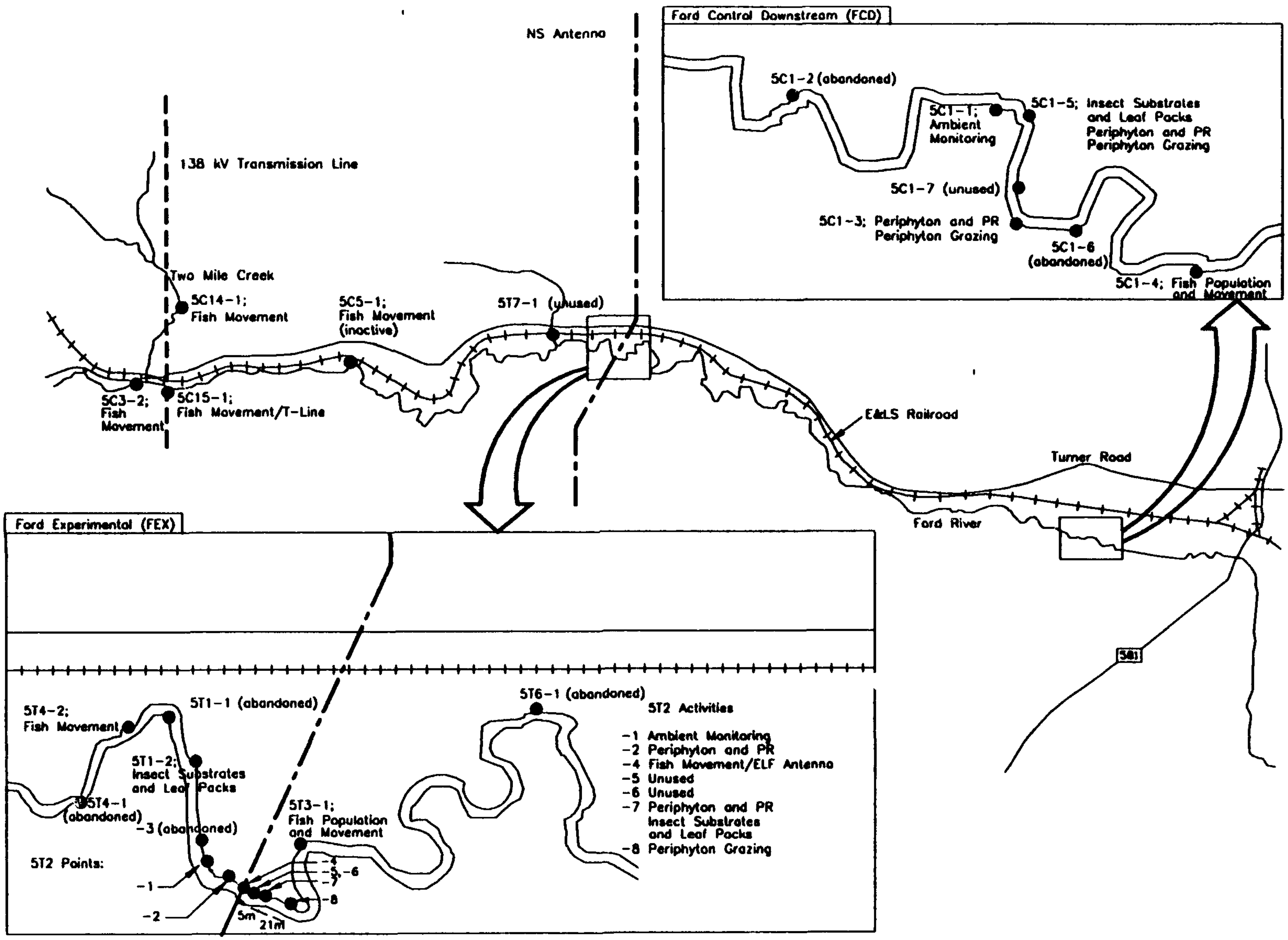


FIGURE 4. AQUATIC ECOSYSTEMS STUDY SITE LOCATIONS.

recalculated using 1991 measurement data and are presented, together with 1990 ratio calculations, in Table 1. Original and new site pairings are included in this table for easy comparison of EM ratios before and after the establishment of the new study locations. New sites are designated with an asterisk. In all cases, the R1 ratio for new site pairings remains improved over the original pairings.

In support of an earthworm reproduction study begun in 1991, a suitable location was needed for gathering earthworm populations. Site requirements included an abundant supply of a specific earthworm species found at both the treatment and the control study sites, and EM field intensities that met control site exposure criteria. The latter was necessary to assure that previous exposure of the collected worms to EM fields would not confound experimental results. IITRI performed EM field measurements at two locations sited by the principal investigator for these studies as having appropriate worm populations. The site locations, 3S1-1 and 3S2-1, are identified in Figures C-1, C-4, and C-5. EM field intensities at both locations were well within control site exposure criteria, making either site appropriate

TABLE 1. R1 EM FIELD INTENSITY RATIOS ($T_{(76\ Hz)}/C_{(76\ Hz)}$)
Aquatic Ecosystems Studies

Compared Sites (Treatment/Control)	Activity	E_A 1990	E_A 1991	E_E 1990	E_E 1991	B 1990	B 1991
5T1-2/5C1-5	Insect Substrates and Leaf Packs	42	35	2.6	2.6	66	49
5T2-7*/5C1-5	Insect Substrates and Leaf Packs	6700	2800	6.9	6.2	600	440
5T2-2/5C1-5	Periphyton and PR	270	1020	5.0	4.8	300	300
5T2-7*/5C1-5	Periphyton and PR	6700	2800	6.9	6.2	600	440
5T2-2/5C1-3*	Periphyton and PR	270	1020	7.6	7.9	300	310
5T2-7*/5C1-3*	Periphyton and PR	6700	2800	10.6	10.1	600	460
5T2-8/5C1-5	Periphyton Grazing	1080	1510	7.7	6.7	340	310
5T2-8/5C1-3*	Periphyton Grazing	1080	1510	11.9	11.0	340	330

E_A=air electric field.
E_E=earth electric field.
B=magnetic flux density.

*Locations added in 1990 to improve the R1 ratio for E_E.

for the collection of needed worm populations. For the sake of convenience, location 3S2-1 was used exclusively in 1991. Further descriptions of the engineering support for this study, including determination of locations within the study sites for the *in situ* incubation bags used to isolate worm populations, are presented in Section 4.2.

3. ANNUAL EM FIELD MEASUREMENTS

3.1 Description of EM Fields of Interest

The three EM fields under investigation in this program are the magnetic field, the earth electric field, and the air electric field.

A magnetic field is generated by current passing through a conductor. The ELF Communications System and power lines both produce consistent and predictable magnetic fields that are generally unaffected by environmental factors such as weather, vegetation, soil, and nonmetallic structures. Magnetic fields are unchanged at such boundaries as air/earth or air/water. Thus, measurement techniques need not consider shielding, enhancements, or perturbations of the magnetic field from the local environment. This local uniformity of the magnetic field allows precise measurements over time, provided that the field sources--in this case, the ELF antenna and power line currents--remain constant.

The electric field in the earth is measured as a difference in longitudinal potential at the surface of the earth. The two sources of earth electric field associated with the ELF Communications System are (1) that induced by the magnetic field and (2) that generated by the ground terminal currents. The 60 Hz earth electric field is induced by power line magnetic fields and is also generated by unbalanced 60 Hz earth return currents associated with power distribution systems. The uniformity of earth electric fields is affected by the conductivity of soil and other factors such as large rocks, tree roots, and pools of water. Generally, the intensity of earth electric fields is fairly uniform and measurements are repeatable when anomalies are avoided. Some year-to-year variations may occur because of changes in soil moisture content, which affect soil conductivity.

The electric field in the air is generated as a result of the operating voltage or transverse potential of the ELF antenna wire with respect to ground and also as a by-product of the earth electric field. Power lines generate a transverse or vertical air electric field in a manner similar to that of the overhead antenna wire. These vertical fields are limited to the ROW and other nearby cleared areas. A difference in potential between two grounded objects such as trees is set up by the earth electric field. This difference in potential in turn generates a horizontal electric field in the air. Both the horizontal and vertical air fields are perturbed by vegetation, people, and instrumentation, all of which are more conductive than air. The perturbations of the field may take the form of an enhancing of the ambient field near objects or as a shielding effect on the surroundings. This results in a high variability of the air electric field over a small area. Efforts are made to measure the air electric field in open areas in order to determine the magnitude of the unperturbed field.

3.2 EM Field Measurement Equipment

3.2.1 Field Probes and Meters

The magnetic flux density, air electric field intensity, and earth electric field intensity are measured using directional field probes designed and calibrated by IITRI. Each of these probes, when placed in the existing electric or magnetic field, outputs an ac voltage proportional to the field intensity. The meter used to measure the output voltages of the probes is a Hewlett-Packard 3581A signal wave analyzer. The HP 3581A functions as a frequency selective, rms-calibrated voltmeter with factory modifications for battery and 1 Hz bandwidth operation. A 3 Hz bandwidth is used to measure 60 Hz and unmodulated ELF signals, but a wider bandwidth is needed to measure modulated ELF signals. Because the wider bandwidth will include 60 Hz signals produced by power lines, an IITRI-fabricated active notch filter is placed in series with the wave analyzer when the 60 Hz and ELF signals are of similar magnitudes in order to remove the 60 Hz signals and their harmonics. The output voltage of a probe is multiplied by the calibration factor of the probe at the frequency of interest to obtain the magnitude of the applied field.

The magnetic field probe is basically a multiturned coil of wire wound on a ferrite core and shunted by appropriately chosen resistors to obtain a flat frequency response. The probe generates an output voltage that is proportional to the magnetic flux density parallel to the axis of the core. This voltage is converted to the magnetic flux density by means of a calibration factor determined prior to each field outing. Two sizes of these probes are shown in Figure 5.

The earth electric field probe consists of three electrodes mounted on a fiberglass frame so as to form two orthogonal 1-m-spaced electrode pairs (Figure 6). The electrodes are pushed into the earth, and a switch connects a voltmeter across one pair of electrodes at a time. The voltage measured across each pair of electrodes is equal to the earth electric field in the given direction. Note that a compass and a cradle are mounted atop a 1-m vertical stalk that is hinged at the juncture of the probe legs. The compass aids in alignment of the probe legs prior to raising the stalk. The cradle is designed to hold the magnetic field probe in three orthogonal positions at a 1-m height and orient the probe precisely with the legs of the earth electric field probe.

The air electric field probe consists of a spherical sensor/transmitter, an analog fiber-optic data link, and a receiver (Figure 7). The probe produces an output voltage proportional to the air electric field along the primary axis of the spherical sensor/transmitter. This voltage is converted to the electric field intensity by means of a calibration factor determined prior to each field outing. The calibration factor and probe operation are checked periodically using a portable electric field probe calibrator. For protection and insulation, a styrofoam-and-plastic shell is placed over the probe during measurements in very cold weather.

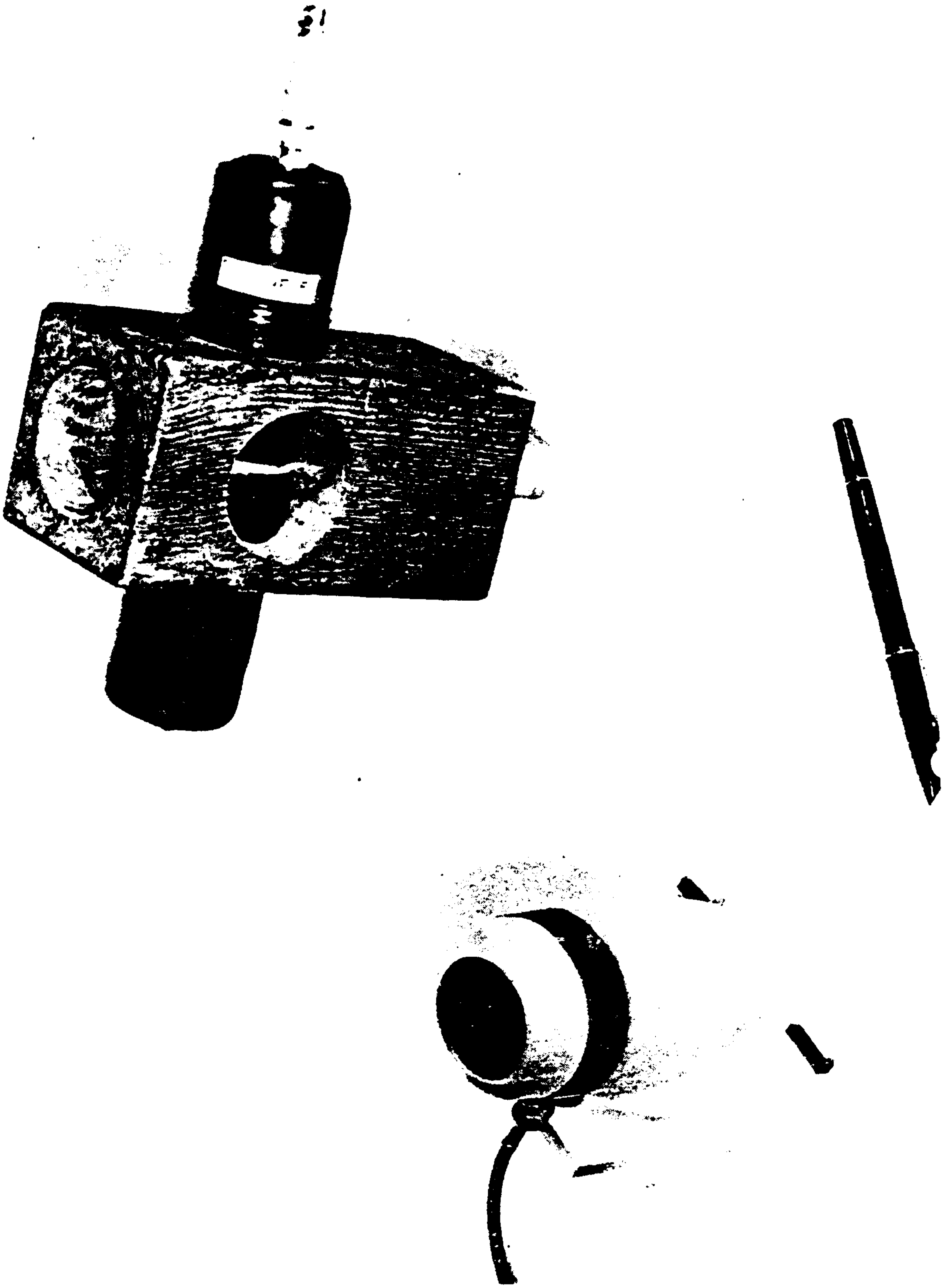


FIGURE 5. MAGNETIC FIELD PROBES.

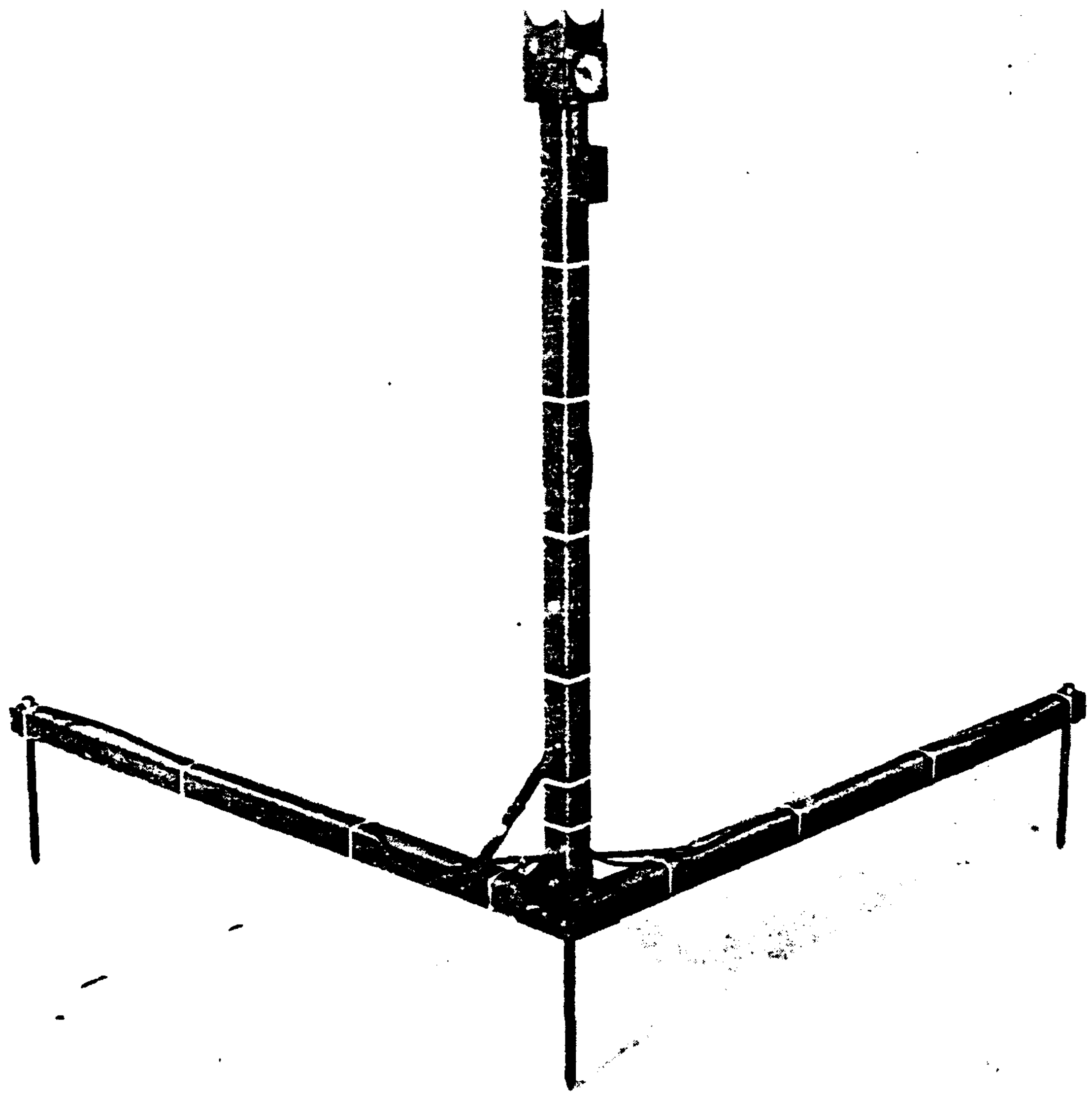


FIGURE 6. EARTH ELECTRIC FIELD PROBE.

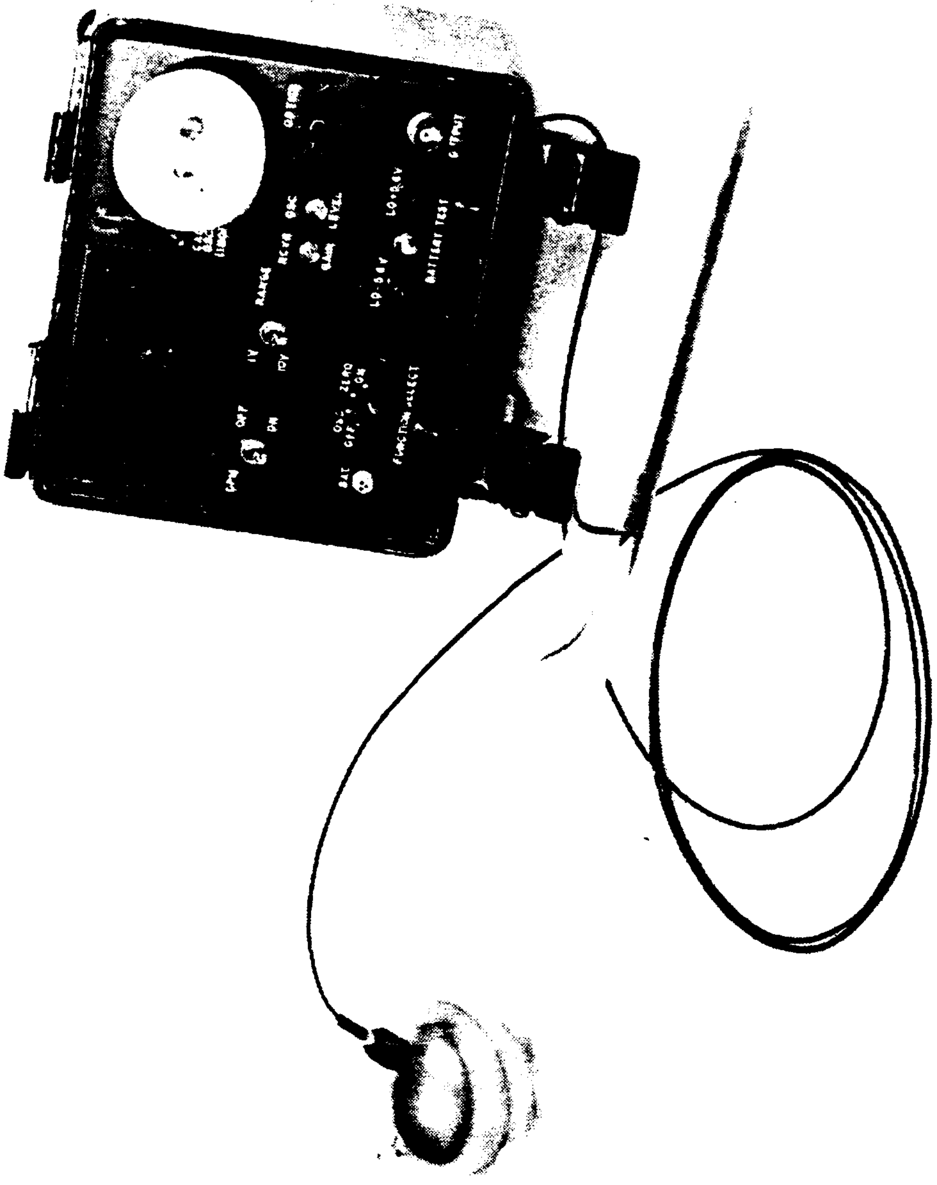


FIGURE 7. AIR ELECTRIC FIELD PROBE.

3.2.2 Field Probe Calibrations

IITRI has developed a computer-driven system for calibrating electric and magnetic field probes over their usable frequency range (see Figure 8). At the heart of the system are:

- a Hewlett-Packard 86B computer equipped with an IEEE 488 instrument interface bus
- a Hewlett-Packard 3421A data acquisition unit
- a Valhalla 2703 precision ac calibrator.

The calibration system generates a uniform electric field between a pair of 1-m-square, 1/3-m-spaced parallel plates with guard rings. A uniform magnetic field is generated over a large volume by a set of 1-m-radius Helmholtz coils.

The calibration system produces both a table of each probe's calibration factors and a plot of the probe's transfer function versus frequency. The magnetic field probe and air electric field probe are calibrated before and after each use, and a record is kept of all calibrations.

The magnetic field probe calibration fluctuates by no more than ±1% over a one-year period. This probe is constructed entirely of passive components, making routine calibration checks during field measurements unnecessary. The earth electric field probe, which consists solely of a perpendicular pair of 1-m-spaced electrodes, requires no calibration, and its mechanical stability is excellent. The air electric field probe calibration fluctuates by no more than ±5% over a one-year period. There is little difference in the calibration of this probe with or without its insulating styrofoam-and-plastic shell. Portable electric field calibration plates are used during field measurements so that probe operation can be verified periodically.

3.3 EM Field Measurement Techniques and Protocols

3.3.1 Determining EM Field Magnitudes

The magnitude of an EM field vector is determined by measuring its orthogonal components. This requires measurements with the field probe oriented along three orthogonal axes. For simplicity and repeatability, the axes chosen are aligned in the north-south, the east-west, and the vertical directions. The earth electric field intensity has no vertical component; therefore, only the north-south and east-west components are measured. In the case of the air electric field and magnetic flux density, all three orthogonal field components are measured. The orthogonal measurements are then used to compute a vector sum or maximum.

One disadvantage of the orthogonal components method is that it yields the correct field maximum only when a single field source is present or is dominant. Fortunately, this is generally the case for the ecological monitoring sites in the ELF System areas. When more than one field source is present, the computed vector sum will be conservative; that is, it will be greater than or equal to the actual maximum. Measurements were made in Wisconsin at those sites where a single antenna did not dominate, and

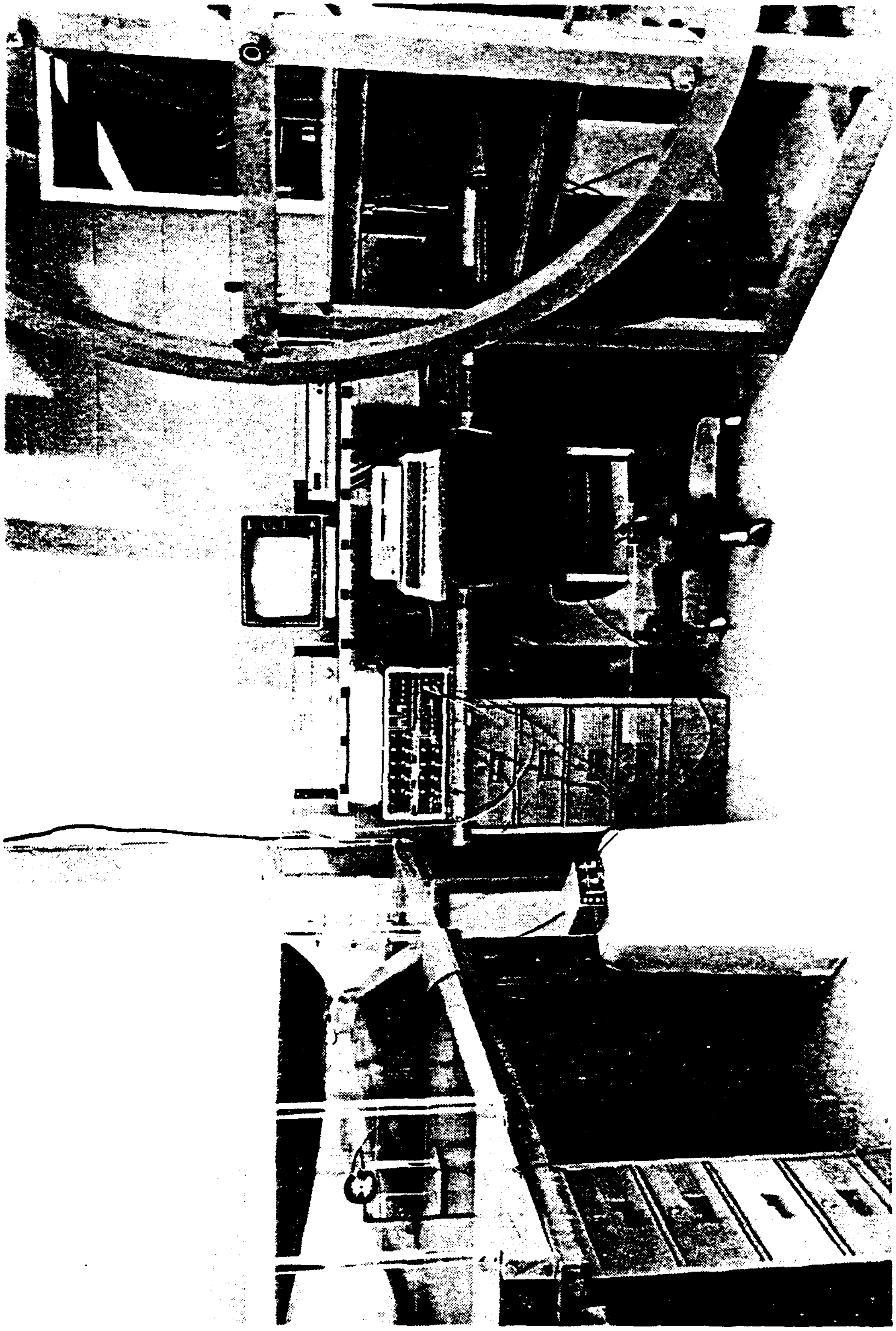


FIGURE 8. COMPUTER-DRIVEN ELECTRIC AND MAGNETIC FIELD PROBE CALIBRATION SYSTEM.

site-specific correction factors (typically less than 5%) were determined for calculating actual field magnitudes from the vector sum magnitudes. Similar measurements have not been possible in Michigan. Only a few Michigan migrating bird population transect sites, however, fall in this category. Further, correction factors are generally only necessary for the earth electric field, which is considered of secondary importance for this study.

3.3.2 Measurement Conditions--Michigan

Construction of the NRTF-Republic began in 1984 and continued through 1985. During this period, the NRTF-Republic was not capable of generating ELF EM fields. Construction of the NRTF-Republic was completed in early 1986 and, subsequently, intermittent operation began with low power levels of 4 to 10 amperes of antenna current. Only one antenna or antenna element was operated at any one time during 1986. These were the north-south (NS) antenna, the north east-west (NEW) element, and the south east-west (SEW) element. From 1987 onward the NEW and SEW antenna elements have been connected in parallel and operated as one antenna, hereafter referred to as the east-west (EW) antenna. The NRTF-Republic operated intermittently with a 15-ampere antenna current in 1987, and intermittently with 75-ampere antenna currents during 1988 and early 1989. During 15- and 75-ampere operation, only one antenna was operated at any one time. From May 1989 onward, the NRTF-Republic operated both antennas (NS and EW) simultaneously, at a full-power current level of 150 amperes. Both modulated and unmodulated signals were employed.

Table 2 summarizes the predominant operating conditions under which measurements have been made in Michigan. In all cases, the orthogonal components of the magnetic flux density and of the transverse and longitudinal electric fields were measured, and a vector sum magnitude was computed for each EM field. Unless otherwise stated, this vector sum magnitude is the value reported in all measurement documentation.

The following subsections describe the 1986-1991 measurement protocols used in Michigan.

3.3.2.1 1986 Conditions. The 1986 EM measurement protocol for Michigan was as follows:

- Ambient 60 Hz EM fields were measured with the NS antenna and both EW antenna elements off.
- 76 Hz EM fields from the NS antenna were measured with both EW antenna elements off.
- 76 Hz EM fields from the NEW antenna element were measured with the NS antenna and the SEW antenna element off.
- 76 Hz EM fields from the SEW antenna element were measured with the NS antenna and the NEW antenna element off.

All measurements were made using a meter bandwidth setting of 3 Hz to discriminate the frequency of interest.

TABLE 2. ANTENNA OPERATING CONDITIONS DURING EM FIELD MEASUREMENTS IN MICHIGAN

Year	Antenna or Element	Antenna Current, A	Frequency, Hz	Modulation	Phase	"Off" Antenna Status at Transmitter
1986	NEW, SEW, or NS	6 (NEW) 6 (SEW) 4 (NS)	76	No	N/A	GND
1987	NS or EW	15 (NS) 15 (EW)	76	No	N/A	CON
1988	NS or EW	75 (NS) 75 (EW)	76	No	N/A	CON
1989	B	150 (B)	76	PT	86°	N/A
1990	B	150 (B)	76	Yes	86°	N/A
1991	B or NS	150 (B) 150 (NS)	76	Yes	99°	GND

B = both antennas simultaneously.
NS = north-south antenna only.
EW = east-west antenna only.
NEW = north EW element only.
SEW = south EW element only.
PT = part time.
N/A = not applicable.
GND = grounded at transmitter.
CON = connected to transmitter.

3.3.2.2 1987, 1988 Conditions. In 1987 and 1988, the EM measurement protocol for Michigan changed from the 1986 protocol to account for the new EW antenna configuration. That revised protocol was as follows:

- Ambient 60 Hz EM fields were measured with both antennas off.
- 76 Hz EM fields from the NS antenna were measured with the EW antenna off.
- 76 Hz EM fields from the EW antenna were measured with the NS antenna off.

All measurements were made using a meter bandwidth setting of 3 Hz to discriminate the frequency of interest.

3.3.2.3 1989 Conditions. In 1989 the EM measurement protocol for Michigan changed again because of simultaneous operation of the NS and EW antennas during all measurements. Modulated signal operation also necessitated protocol modifications. The 1989 protocol was as follows:

- Ambient 60 Hz EM fields at control study sites were typically measured during operation of both antennas but could be measured under any antenna operating conditions with a 3 Hz meter bandwidth.

- Ambient 60 Hz EM fields at treatment study sites were measured either with the antennas off or operating with an unmodulated signal. Measurements of 60 Hz fields at treatment sites could not be made during modulated signal operation.
- 76 Hz ELF EM fields were measured with both antennas on and with either modulated or unmodulated signal. Meter bandwidths were 30 Hz or 3 Hz, respectively.

3.3.2.4 1990, 1991 Conditions. In 1990 and 1991, the EM measurement protocol for Michigan changed little from 1989. The significant difference is that essentially all antenna operations in 1990 and 1991 were with a modulated signal, making it impossible to measure 60 Hz EM fields at treatment sites unless the antennas were off. As a result, efforts were made in 1990 and 1991 to visit treatment sites during antenna operation and maintenance periods in order to make both 76 and 60 Hz EM field measurements. Also, in 1991 there were significant periods of time when the EW antenna was down for maintenance. Efforts were made to take EM field measurements at various sites during this condition in order to estimate its effect on EM field intensities at all study sites. The 1990 and 1991 protocol was as follows:

- Ambient 60 Hz EM fields at control study sites were typically measured during operation of both antennas but could be measured under any antenna operating condition.
- Ambient 60 Hz EM fields at treatment study sites were measured with the antennas off.
- 76 Hz ELF EM fields were measured with both antennas on and in some cases in 1991 with the NS antenna on and EW antenna off with a modulated signal in both cases.

Unmodulated ELF and 60 Hz EM field measurements were taken using a meter bandwidth setting of either 1 Hz or 3 Hz to discriminate the frequency of interest. Modulated ELF signals were measured using a meter bandwidth setting of 30 Hz. A 60 Hz notch filter was employed at some control sites to allow measurement of modulated ELF signals.

3.3.3 Selection of Measurement Points

Measurement points at study sites were selected to define the spatial variation of the 76 Hz EM fields over each site. This was done on the basis of the size and shape of a site and its location relative to the antenna elements, as described below.

Control sites, all of which are several miles from the nearest antenna element, are expected to have minimal EM field gradients. At small control sites, a single measurement point was deemed sufficient to characterize the EM fields. Intermediate-size control sites were measured at the points nearest to and farthest from the antenna grid. Large control sites were measured at several more points in order to accurately define the EM field gradients across them.

EM field gradients across treatment sites are larger than gradients at control sites. Multiple measurements were generally necessary at all treatment sites. The selection of measurement points for

the treatment sites was based on one of four strategies dictated by the nature of the site. For sites comprising long, narrow transects parallel to the antenna (e.g., the bird species and communities studies), measurements typically were taken at the ends of the transect and often at intermediate points along the transect. For sites of very restricted area (e.g., the aquatic ecosystems studies), only one measurement was made at each experiment location. Two other measurement strategies were applied at treatment sites covering a large area. For those sites arranged with well-defined, grid-like borders, measurements were made at the borders or corners of the plots such that the measurements encompassed the study area and bounded the field levels. For those sites with irregular borders, such as those for the nesting birds study, measurements were made along a transect perpendicular to the antenna, typically at 25-m intervals, to provide a profile of the field gradients.

These measurement point selection techniques allow the investigators to estimate the EM field intensity at any point of interest within a study plot. Such estimates can be made based on the fact that the EM fields vary greatly with distance from the antenna but show little variation along a path parallel to it. Therefore, given the distance of a point of interest from the antenna, the EM fields can be estimated by linear interpolation between measured values at greater and lesser distances from the antenna. Because the EM fields vary little along a path parallel to the antenna, the point of interest and measured points do not need to be at the same lateral position along the length of the antenna. The accuracy of field estimations for any point can be improved by plotting the EM field gradients as a function of distance from the antenna and using graphical rather than linear interpolation between measured points. This technique can be applied to the field profiles for the nesting birds study sites and the upland flora and soil microflora study sites, which appear in Appendixes A and D.

3.4 Summary of 1991 Annual Measurement Data

Annual measurements in Michigan were conducted on 6-8 and 29-30 May, 19-20 June, 23-27 and 30 September, and 1-4 and 15-17 October 1991. All active sites were measured during these periods with the exception of laboratory sites, where measurements were not conducted in 1991.

Table 3 presents a summary of the number of sites and measurement points examined during 1991. As shown, a total of 195 measurement points were needed to characterize 50 sites. The number of measurement locations per site was determined by plot size, the presence of known or anticipated EM field gradients, and the information needed by the study investigators for statistical analyses.

3.4.1 Michigan Measurement Data

The data taken during the 1991 EM measurements in Michigan appear in Appendixes A through G. Six data tables in each of these appendixes document 60 Hz and 76 Hz measurements of the air electric field, earth electric field, and magnetic flux density. In addition, separate tables document measurements taken at the small mammals and nesting birds and native bees laboratories, at fixed probes

TABLE 3. SUMMARY OF 1991 EM FIELD MEASUREMENTS

Study	Number of Measurement Sites: Existing	Number of Measurement Sites: New, 1991	Number of Measurement Sites: Total	Number of Measurement Points: Existing	Number of Measurement Points: New, 1991	Number of Measurement Points: Total
Small Mammals and Nesting Birds	13	0	13	63	0	63
Native Bees	5	0	5	15	0	15
Soil Arthropods and Earthworms	2	2	4	8	10	18
Upland Flora and Soil Microflora	6	0	6	50	0	50
Aquatic Ecosystems	9	0	9	15	1	16
Soil Amoeba	3	0	3	9	0	9
Bird Species and Communities, Michigan	10	0	10	24	0	24
Total	**48**	**2**	**50**	**184**	**11**	**195**

Table does not include laboratory sites.

for the upland flora and soil microflora studies, and at regular intervals along treatment transects of the bird species and communities studies. Details of these measurement activities are discussed in Section 4.

In each appendix, the tables of 60 Hz data appear first. Each table contains a separate column of data for each year from 1983 through 1991. A footnote for each column describes the physical status of the ELF antenna during the 60 Hz measurements for that year. The physical status of the ELF antenna has a significant impact on the 60 Hz EM fields measured at treatment sites, because it affects the degree of coupling to the antenna of 60 Hz EM fields generated by nearby power lines. This phenomenon is explained in Section 3.4.2.

Following the 60 Hz data tables are tables containing 76 Hz EM field intensities measured in 1986 through 1991. The 76 Hz EM field intensity data have been taken at several different antenna operating currents, ranging from 4 amperes in 1986 to the full operating power of 150 amperes in 1989, 1990, and 1991. Specific operating currents are given in the column headings of the data tables. EM field intensity values, as shown in the data tables, have increased in proportion to the antenna operating current from 1986 through 1991.

3.4.2 Coupling of 60 Hz Fields

The 60 Hz data for Michigan studies in Appendixes A through G show that there were significant yearly fluctuations of the 60 Hz EM fields from 1983 through 1991. The primary factors in these fluctuations were:

- completion of antenna installations in 1986
- parallel connection of the two EW antenna elements in 1987
- differences in antenna-to-power amplifier connections in the antenna "off" mode
- changes in power line loads
- changes in earth conductivity

The first three factors apply only to treatment sites; the last two apply to both treatment and control sites.

The 60 Hz EM fields at the treatment sites are strongly influenced by the presence of the ELF antenna elements. This is because EM fields generated by 60 Hz power lines couple to the conducting loop formed by the ELF antenna, its ground terminals, and the earth. This coupling results in a 60 Hz current flow on the antenna wires that in turn sets up new 60 Hz EM fields nearby. The 60 Hz EM fields generated by the two sources (power lines and antenna) interact at treatment study sites and elsewhere. The general observation has been that the longitudinal electric fields sourced by the power lines and antenna partially cancel each other. The relative magnitude of the resulting EM field is dependent on the intensities of the EM fields generated by the two sources. The magnetic fields from power lines fall off more rapidly than the longitudinal electric fields, and they do not appear to significantly interact with the 60 Hz magnetic fields from the antenna. The result is that 60 Hz magnetic fields near the antenna are greater in magnitude than those measured prior to antenna construction.

The coupling of ambient 60 Hz fields to the ELF antenna was first observed in 1986, coincident with the completion of antenna construction in Michigan. This coupling will continue as long as the ELF antenna and power lines are present. Year-to-year differences in the treatment site 60 Hz EM fields are likely due to changes in coupling to the antenna elements resulting from changes in antenna configuration and to changes in 60 Hz power line loads. The antenna configuration changes have been the parallel connection of the two EW antenna elements beginning in 1987 and differences in the antenna connections to the power amplifiers in the antenna "off" mode--the antenna condition under which most 60 Hz measurements are made.

In 1988, 60 Hz coupling to the NS antenna appeared to have increased substantially. This correlates with large load increases on a transmission line that parallels the NS antenna element about four miles to the west. Since the Presque Isle power plant was purchased by Wisconsin Electric Power Company in January 1988, its subsequent operation as a major producer of electrical energy in the region suggests that this line will remain heavily loaded.

Variations in the 60 Hz EM fields at control sites are not related to the location of the ELF antenna or its configuration. Variations here are most likely the result of varying power line currents and temporal changes in earth conductivity. These same factors also influence the 60 Hz EM fields at treatment sites, but not necessarily to the same extent.

3.4.3 EW Antenna Shutdown

The EW antenna was off for special repairs from 8 May through 12 July 1991 and again from 23 December 1991 continuing into 1992. During these periods, normal operation of the NS antenna with a 150-ampere, 76-Hz MSK signal continued. EM intensities during the EW antenna shutdown may be estimated by using 1988 measurements (EW antenna off, NS antenna on with 75-ampere current) and extrapolating to the 150-ampere condition (i.e., 1988 value times 2). For treatment study sites along the NS antenna ROW, the EW antenna typically contributes about 1% of the total field intensity based on 1988 measurement data. Field intensities at these sites, therefore, are expected to have changed little when the EW antenna was taken out of service. This was shown for the aquatics study where 1991 EM field measurements taken during operation of the NS antenna only were consistent with measurements taken during operation of both antennas in 1989 and 1990 (see Appendix E). Exceptions to this are the earthworm and soil arthropod study treatment site and some bird species and community study treatment transects, which although located along the NS antenna ROW are close enough to the EW antenna that its contribution may be as much as 10%.

The impact of the EW antenna shutdown was greatest for treatment study sites near the EW antenna or its ground--namely, the two treatment sites for the upland flora and soil microflora studies and the Schwartz Creek and part of Flat Rock Creek treatment transects for the bird species and community studies. Measurements were taken at all points for the upland flora and soil microflora treatment study site while the EW antenna was out of service and during operation of both antennas. The fields were reduced to about one-third their normal intensity level during shutdown of the EW antenna--actual values can be obtained from the tables in Appendix D. All 1991 measurements at the bird species and community study sites were taken during operation of both antennas. Predictions of EM field intensity reductions during shutdown of the EW antenna for various transects are presented in Appendix G.

EM field reductions at control study sites during shutdown of the EW antenna are expected to differ greatly depending on the relative position of each study site to the NS and EW antennas. Actual reduction levels are of less concern for these sites, however, since low 76 Hz EM field intensities are desirable there. Any reduction of this field, therefore, will only serve to improve treatment/control site exposure ratios.

4. ENGINEERING SUPPORT ACTIVITIES

4.1 Soil Amoeba Growth Chambers

4.1.1 Background

The soil amoeba and now-completed slime mold studies both employed culture chambers that isolate the study organisms from the surrounding soil. This *in vitro* procedure allows close monitoring of biotic end points without contamination from other soil organisms.

Culture chambers for both studies were buried in the earth at shallow depths thus exposing the cultures of soil amoeba and slime mold to the earth's ambient temperature. It is also desirable to expose the cultures to the same EM environment that they would encounter if living in the soil or litter layer. This was accomplished using a set of collector electrodes in the earth to drive currents through the chamber. Because of a mismatch between conductivities of the earth and chamber, however, it was necessary to add external control circuitry to regulate the drive voltages and currents in order to match the electric field and current density in the chamber to that in the earth. Furthermore, because the electric field and current density are related by conductivity, it was impossible to match both fields in the same chamber to that in the earth. Instead, two basic culture chamber drive control circuits were developed: one for matching electric field exposure and the other for matching current density exposure between the chambers and the earth. The drive control circuits for the soil amoeba chambers and an exposure setup protocol explaining their use are detailed in Appendix I. Similar information for the slime mold study may be found in a previous report.[5] The magnetic flux is not perturbed by the culture chambers, and thus their magnetic flux density is the same as that of the surrounding earth for all chambers.

4.1.2 Monitoring of Soil Amoeba Growth Chambers

Culture chambers and control apparatus have been installed at the soil amoeba study sites during the years 1987-1991. Control voltages V_{CL} and V_R are measured according to the protocol outlined in Appendix I. Culture chamber electric field (E_{CL}) and current density (J_{CL}) are calculated from the measured voltages as follows:

$$E_{CL} = \frac{V_{CL}\ \text{(volts)}}{0.113\ \text{m}} \quad \text{(V/m)} \tag{5}$$

$$J_{CL} = \frac{V_R\ \text{(volts)}}{R\ \text{(ohms)}\ 1.42 \times 10^{-4}\ \text{m}^2} \quad (\text{A/m}^2) \tag{6}$$

where 0.113 m is the measured distance between culture chamber electrodes, and 1.42×10^{-4} m^2 is the cross-sectional area of the culture chamber growth medium, assuming a chamber half full of medium.

IITRI designed and installed microprocessor-controlled data loggers in 1988, to continually monitor the culture chamber electric fields and current densities. These and other parameters measured by the data loggers in each year are summarized in Table 4. EM fields at the control site (6C2) were consistently below the logger sensitivity. Therefore, in 1991, the logger electronics were removed for use at other locations. Junction boxes, wiring, and other hardware were left for easy reactivation of a data logger at this site if needed. Plots of the calculated culture chamber current densities and electric field intensities at the antenna and ground treatment sites for the 1988-1991 field seasons are presented and discussed in Appendix F. Rainfall and temperature data are being taken for possible future engineering analyses and are not presented in this report.

TABLE 4. PARAMETERS MEASURED BY SOIL AMOEBA DATA LOGGERS

Measurement Parameter	1988	1989	1990	1991 (except 6C2)
Earth Electric Field	•	•	•	•
Culture Chamber Voltage and Current	•	•	•	•
Data Logger Case Temperature (Soil Temperature Surrogate)	•	•	•	•
Soil Temperature		•	•	•
Rainfall			•	•

4.2 Earthworm Incubation Bags

4.2.1 Protocol Development

In 1991, a pilot study of earthworm reproduction using controlled populations confined to *in situ* incubation bags was begun. These bags are intended to isolate the study populations while subjecting them to essentially the same environmental factors and EM exposures as unrestricted worms. To achieve this, soil-filled nylon mesh bags were used to contain the worms while permitting flow of earth currents through the interface. Development of the study protocol included:

- characterizing the earth electric fields within the bags
- siting burial locations for the bags
- measuring the earth electric fields within the bags after a soil settling period.

A probe consisting of a pair of electrodes fastened 10 cm apart on rigid fiberglass stock was fabricated for measurement of electric fields within the incubation bags. It was tested by comparison measurements with the standard 1-m probe. Experiments were conducted with the 10-cm probe to determine the amount of reduction of the earth electric field intensity inside the worm incubation bags. Various methods of bag installation were tested, and the effects of bag mesh size, soil type, soil compaction, and soil moisture content were investigated. A fine mesh bag was found to reduce the electric field intensity inside the bag to about 25% of that in surrounding soil. Standard nylon window screen of the largest mesh size that would still act as a worm barrier reduced the electric fields inside to between 40% and 70% of those outside. Dry, loosely packed soil was found to cause the most field reduction, whereas water-saturated and highly compacted soil caused the least reduction. A cylindrical, flat-bottomed bag sewn up from the large mesh window screen proved to be the most optimal design. Through careful soil compaction techniques, electric field intensities inside the incubation bags equal to 50% to 55% of the electric field intensities in the surrounding soil were obtained on a repeatable basis.

The locations for the worm incubation bags at the treatment site were selected on the basis of earth electric field intensity. Ideally, the bags at this site would be placed in an area where the electric field intensities were at least twice those found within the historic study plots in order to compensate for the reduced fields inside the bags. However, no electric fields of this magnitude could be found despite a thorough measurement survey of the study area on both sides of the antenna ROW. The maximum electric field intensities measured within areas of acceptable biological habitat were only about 10% greater than the fields within the study plots. These field levels were found along a line 28 m east of, and parallel to, the eastern border of the existing site. Based on electric field measurements taken for other studies located along the NS antenna, it was not expected that a new site having significantly greater earth electric field intensities as well as matched habitat would be easily found. It was therefore agreed to place the pilot study incubation bags for the treatment site along the line described. Measurement points 3T2-7 through 13 were added to the annual measurement regime to characterize the EM environment in this area.

Reduced earth electric field intensities inside the worm incubation bags were not a concern at the control site. It was decided to place the bags within unused plots at the west corner of the study site for convenience and ease of monitoring. Locations of the bags within each study site are diagrammed in Figures 9 and 10. These figures are section enlargements of the study sites diagrammed in Figures C-2 and C-3.

IITRI personnel revisited the earthworm study sites 2-3 weeks after the incubation bags were installed at the recommended locations to measure the earth electric field in each bag. Measurements were taken in the middle of each bag and outside each bag along one or both sides. Tables 5 and 6 give tabulations and analyses of the measurement data. As shown in the field ratio columns, the field intensities

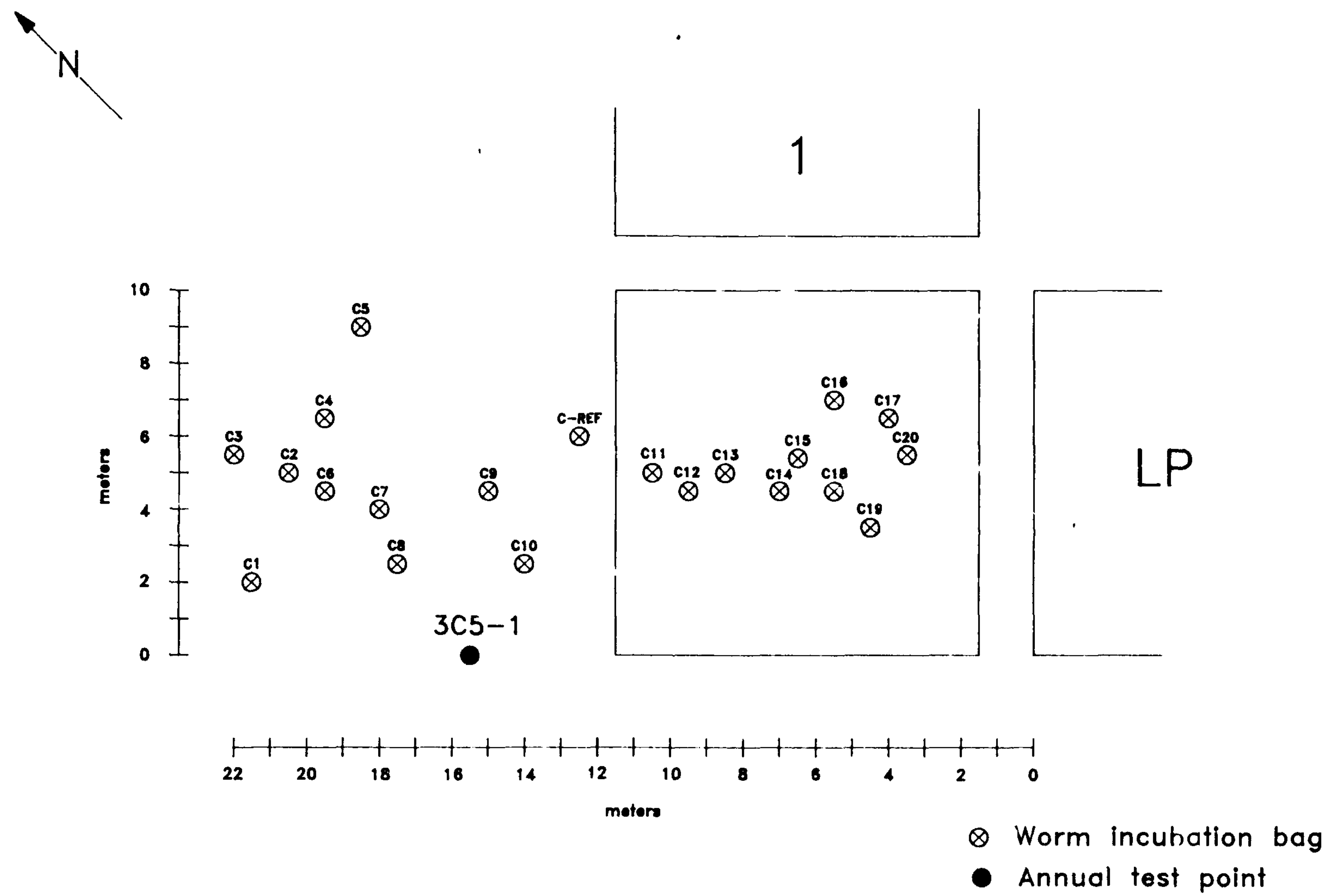


FIGURE 9. WORM INCUBATION BAG LOCATIONS AT TURNER ROAD; 3C5.

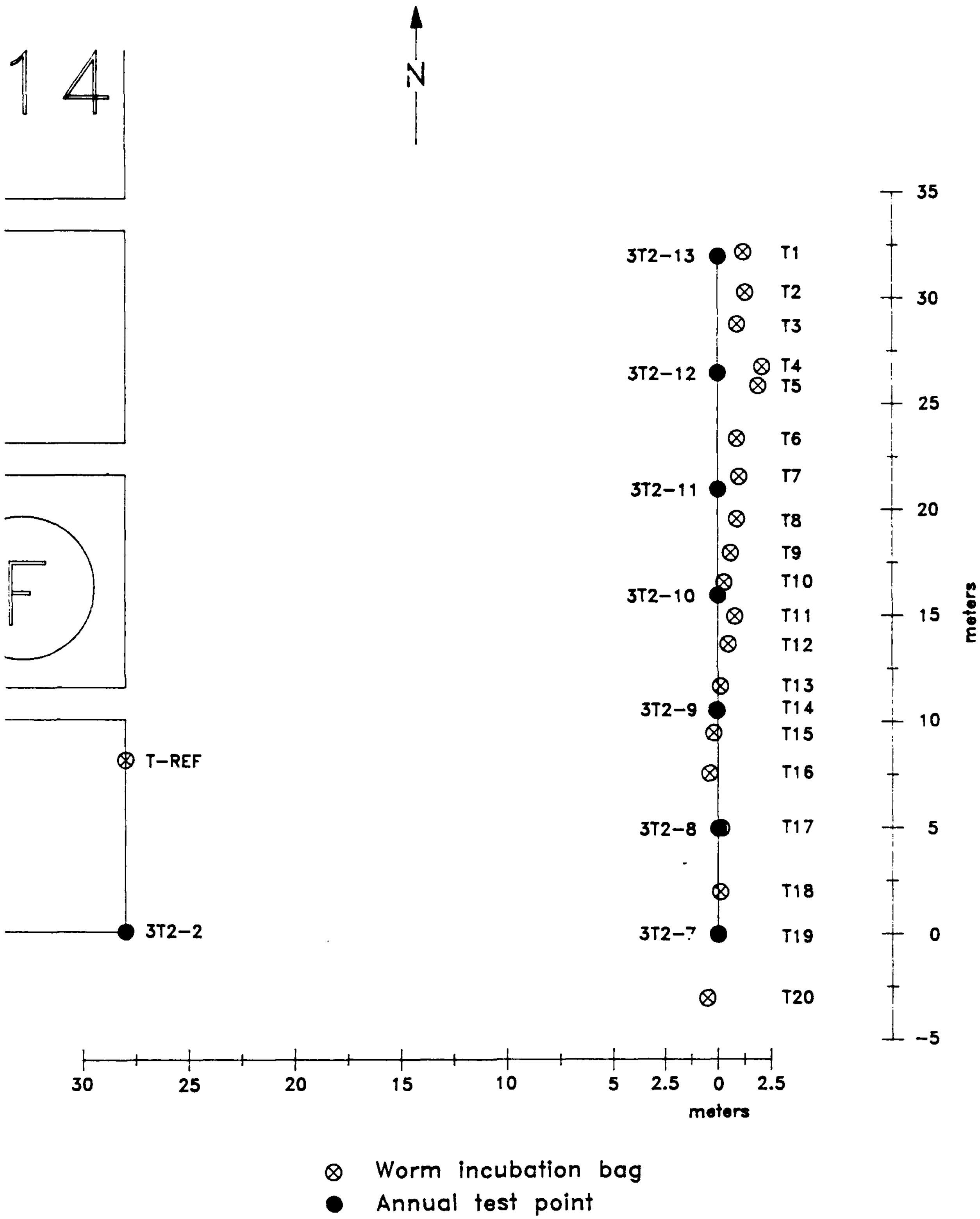


FIGURE 10. WORM INCUBATION BAG LOCATIONS AT SOUTH SILVER LAKE; 3T2.

TABLE 5. CONTROL SITE WORM INCUBATION BAG MEASUREMENTS
Soil Arthropods and Earthworms Studies

Incubation Bag Number	Earth Electric Field Intensity, mV/m*		Field Reduction Ratio
	Next to Bag	Within Bag	
C1	0.110	0.039	0.35
C2	0.185	0.078	0.42
C3	0.130	0.048	0.37
C4	0.100	0.056	0.56
C5	0.23	0.086	0.37
C6	0.21	0.115	0.55
C7	0.170	0.058	0.34
C8	0.22	0.086	0.39
C9	0.21	0.078	0.38
C10	0.22	0.095	0.44
C11	0.155	0.095	0.61
C12	0.26	0.125	0.49
C13	0.190	0.110	0.58
C14	0.160	0.095	0.59
C15	0.120	0.062	0.52
C16	0.095	0.049	0.52
C17	0.26	0.135	0.53
C18	0.36	0.150	0.42
C19	0.68	0.23	0.34
C20	0.22	0.120	0.55
C Reference	0.115	0.067	0.58
Mean	0.21	0.094	0.47
SD	0.13	0.044	0.094

*NS antenna only, 150 A, 76 Hz.

TABLE 6. TREATMENT SITE WORM INCUBATION BAG MEASUREMENTS
Soil Arthropods and Earthworms Studies

Incubation Bag Number	Earth Electric Field Intensity, mV/m*			Field Reduction Ratio
	Next to Bag		Within Bag	
	East Side	West Side		
T1	45	47	22	0.48
T2	52	53	16.5	0.31
T3	60	52	19.5	0.35
T4	60	55	22	0.37
T5	52	43	16.0	0.34
T6	54	64	33	0.56
T7	53	57	30	0.55
T8	42	49	24	0.66
T9	67	64	17.0	0.26
T10	43	40	19.5	0.47
T11	52	53	17.0	0.32
T12	67	70	31	0.45
T13	55	56	21	0.56
T14	52	58	21	0.37
T15	49	54	20	0.39
T16	52	46	22	0.45
T17	52	53	37	0.70
T18	50	50	25	0.50
T19	51	68	36	0.61
T20	53	63	34	0.59
T Reference	51	58	26	0.48
Mean	53	55	24	0.47
SD	6.4	7.9	6.7	0.12

*NS antenna only, 150 A, 76 Hz.

inside the incubation bags ranged from 26% to 70% of those in the surrounding soil. For both sites, the average field intensity inside the bags was 47% of that outside. However, the treatment site bags had slightly more variability than control sites in the amount of field reduction, as reflected by the larger standard deviation (SD) of their field reduction ratios.

4.2.2 Experimental Monitoring

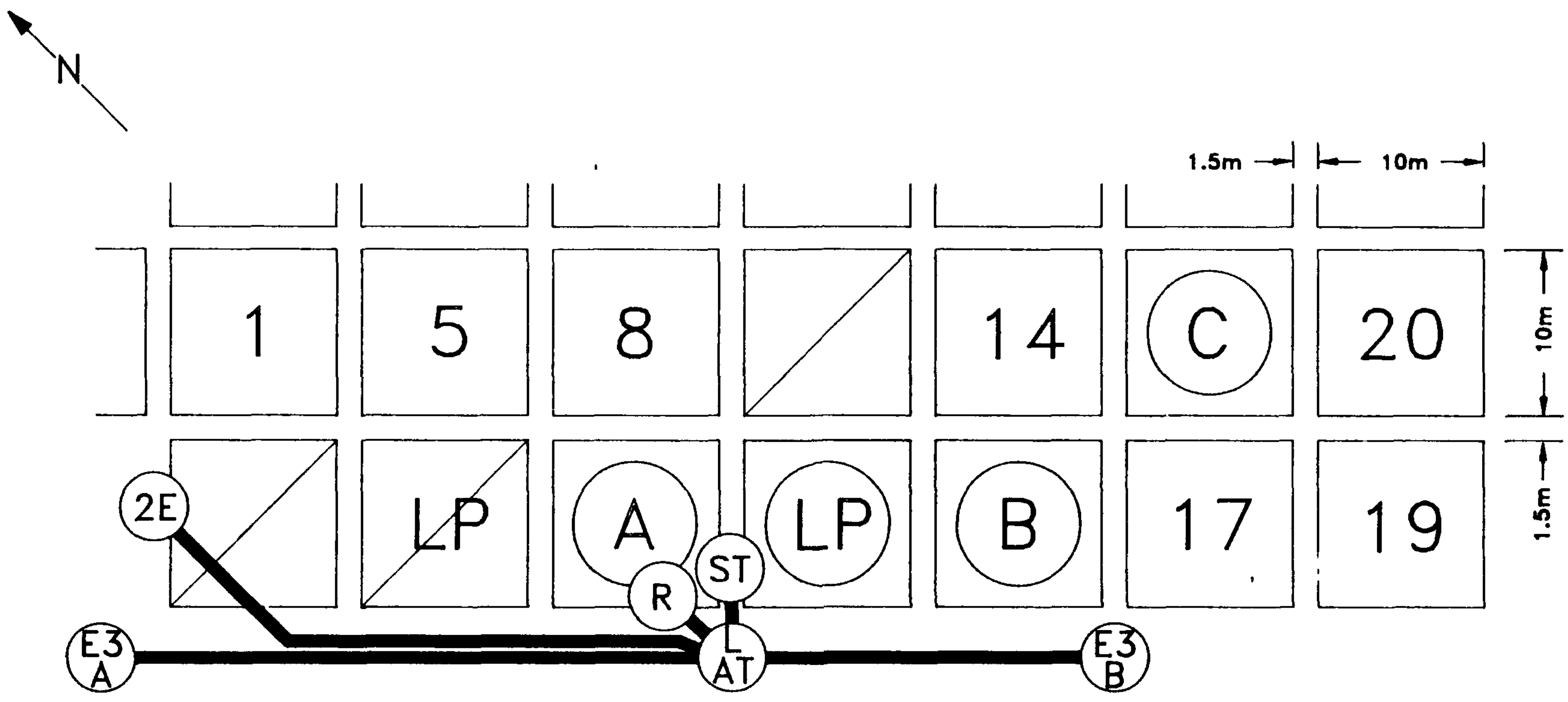
Some monitoring of the earth electric fields in the worm incubation bags was considered necessary to address questions of field variability with regard to such factors as soil settling, soil moisture content, and period changing of bag. Data logger monitoring systems were set up at the two earthworm study sites for this purpose as well as to monitor other variables. The layout of the monitoring systems is shown in the site section enlargements in Figures 11 and 12. One worm incubation bag was set aside at each site to be used as a reference for electric field monitoring. An electric field probe having 1-m-spaced electrodes was installed alongside each reference bag and oriented with the line of maximum field. A 10 cm electric field probe, aligned parallel to its adjacent 1 m probe, was installed inside each reference bag. In this manner the field measurements in the surrounding soil could be used to assess any field variations in the fields inside the bags.

Graphs of earth electric field versus time at the reference incubation bags are presented in Figures 13 and 14. At the treatment site, the field intensities measured by the 1 m probe outside the bag are relatively constant. Within the reference bag, however, large and often abrupt changes in the field intensity are observed. The more abrupt level shifts most likely occurred during bag changeouts when contact with the surrounding soil is disturbed, the soil in the bag is changed, and the alignment of the 10 cm probe may be shifted. Misalignment of the 10 cm probe was noted during the worm bag measurements in late May. The more gradual shifts in field level are probably related to settling of the soil in the bag and to changes in soil moisture and temperature.

The output voltage of the 10 cm probe at the control site was too low to be accurately measured by the data logger; therefore, only the data for the 1 m probe outside C-Ref are presented in Figure 14.

4.3 <u>Characterization of EM Variability</u>

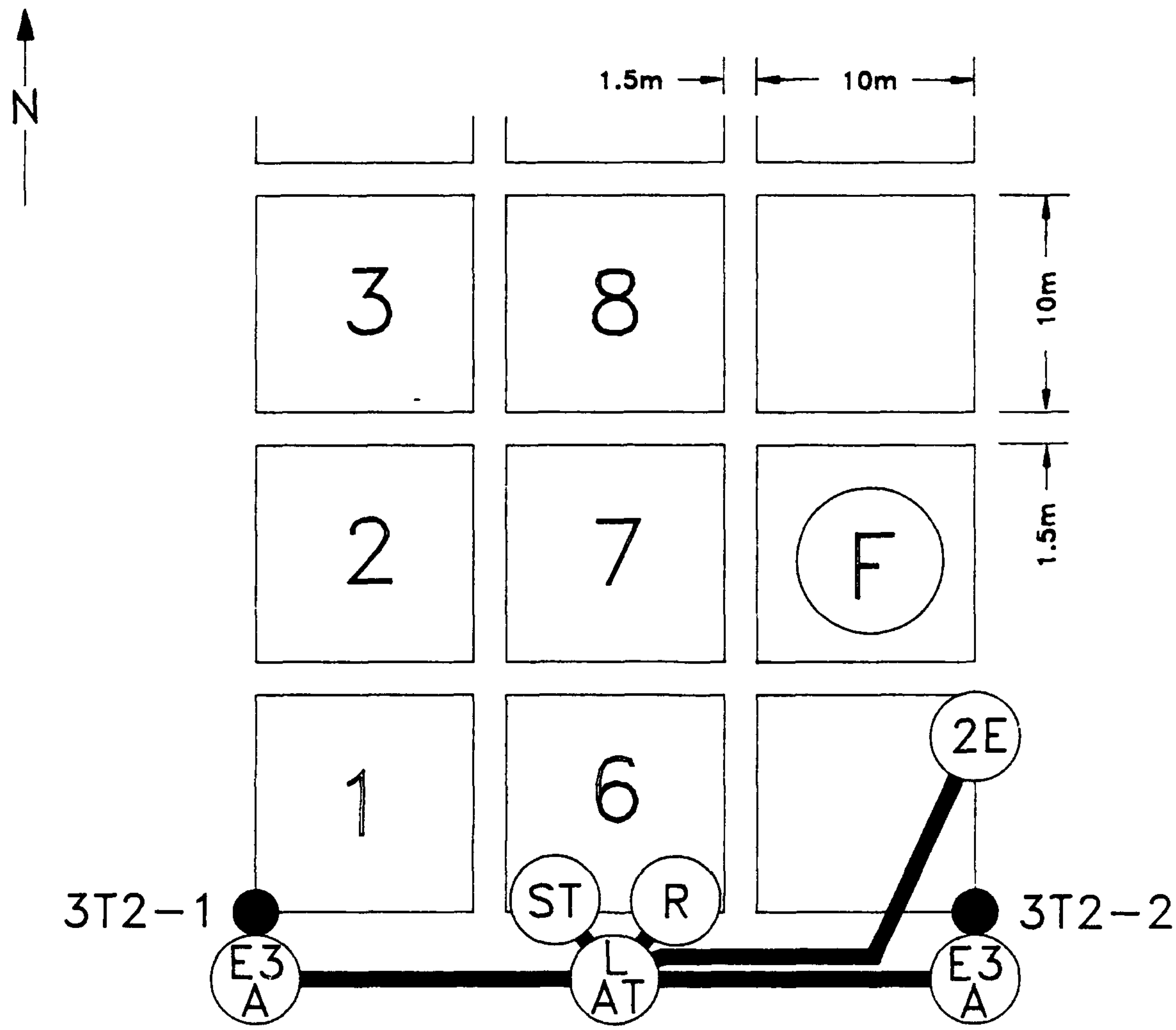
EM field intensity levels are dependent upon several factors making them subject to both spatial and temporal variability. Some of this variation has already been seen in data logger plots from the earthworm study sites and is precisely the reason for the establishment of continuous monitoring systems at these and several other study sites. Strong efforts have also been made through these and other measurements and data analyses to accurately characterize EM field intensity levels at all study areas for all times, as this information is critical in reliably defining the experimental EM exposure for these studies.



KEY

- (L/AT) Data Logger with Air Temperature Sensor
- (ST) Soil Temperature Sensor
- (R) Rain Gauge
- (E3) Three-depth Earth Electric Field Probe
- (2E) Pair of Electric Field Probes at Worm Incubation Bag C-Ref, 10 cm probe inside, 1 m probe outside

FIGURE 11. DATA LOGGER MONITORING SYSTEM AT TURNER ROAD; 3C5.



KEY

- (L/AT) Data Logger with Air Temperature Sensor
- (ST) Soil Temperature Sensor
- (R) Rain Gauge
- (E3) Three-depth Earth Electric Field Probe
- (2E) Pair of Electric Field Probes at Worm Incubation Bag C-Ref, 10 cm probe inside, 1 m probe outside

FIGURE 12. DATA LOGGER MONITORING SYSTEM AT SOUTH SILVER LAKE; 3T2.

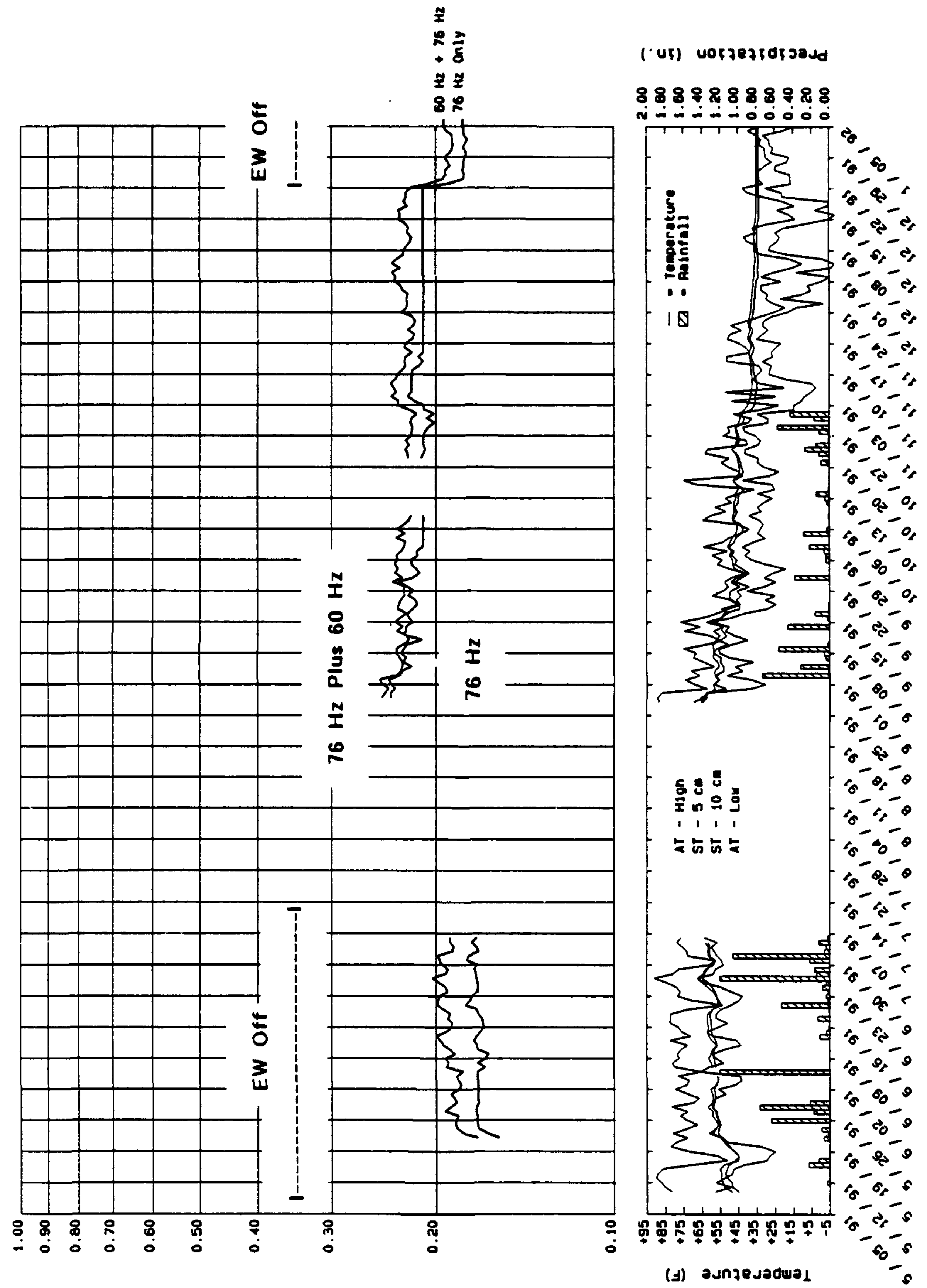


FIGURE 13. CONTROL SITE 1-m PROBE ELECTRIC FIELD MEASUREMENTS NEAR WORM INCUBATION BAG C-REF.

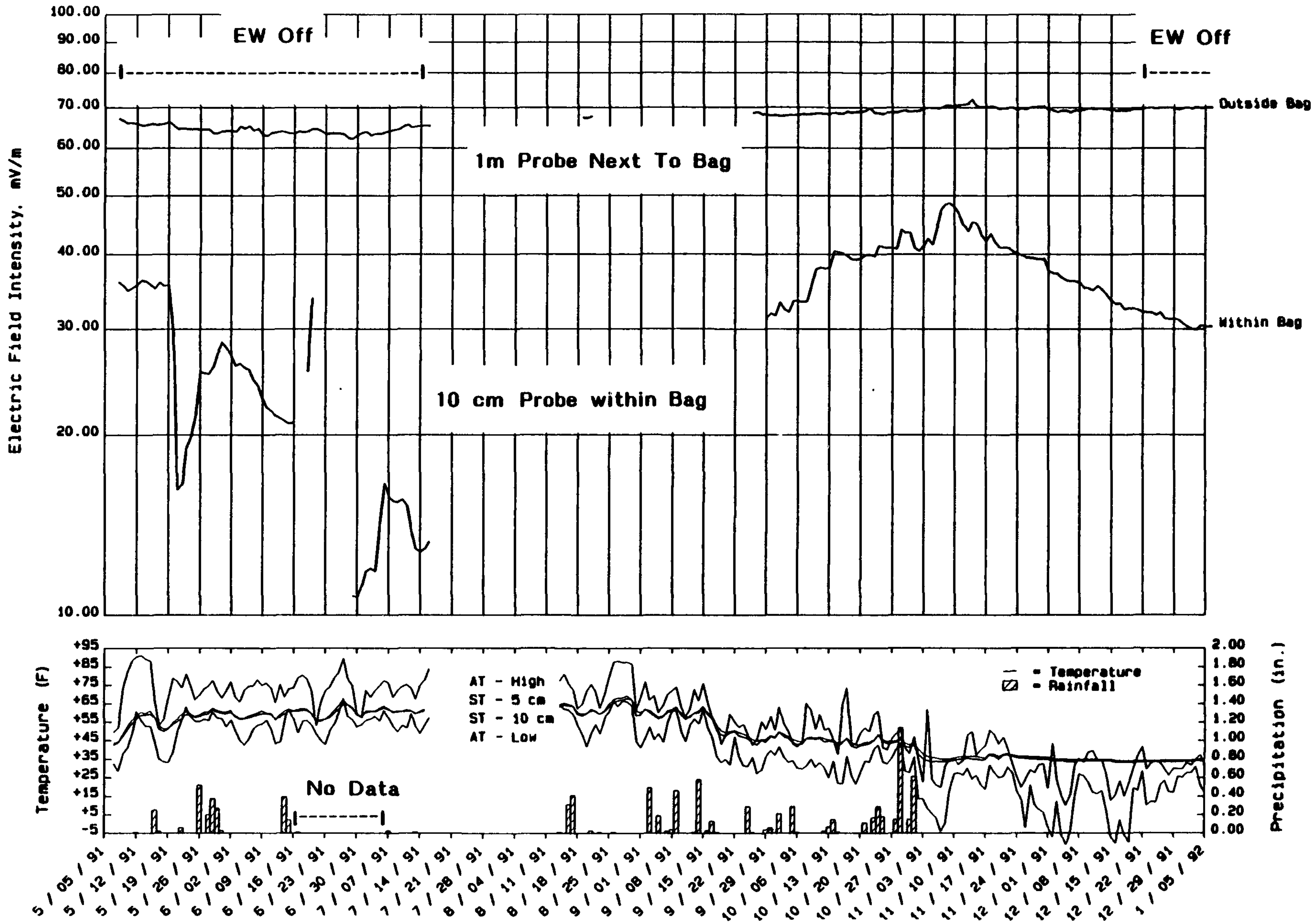


FIGURE 14. TREATMENT SITE ELECTRIC FIELD MEASUREMENTS IN AND NEAR WORM INCUBATION BAG T-REF.

A simplified mathematical description of the three fields of interest is given to help explain variables upon which each EM field is dependent. This is followed by separate discussion and examples of spatial and temporal EM field variability based on engineering support efforts for various studies.

The top diagram in Figure 15 illustrates the orientation of the magnetic flux and earth electric field near an ELF antenna. The earth electric field near a buried ground wire and the air electric field near an ELF antenna are shown in the middle and bottom diagrams of the figure. Equations 7-10 provide mathematical representations for the magnitude of each of these fields.

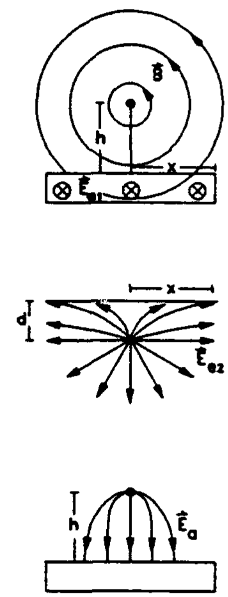


FIGURE 15. EM FIELD ORIENTATIONS.

$$|B| = \frac{\mu_o I}{2\pi\sqrt{x^2 + h^2}} \tag{7}$$

$$|E_{e1}| = -jf\, I\mu_o \ln\left(\frac{1.85}{x\sqrt{2\pi f\mu_o\sigma_B}}\right) - \frac{\pi f\, I\mu_o}{4} \tag{8}$$

$$|E_{e2}| = \left(\frac{I}{\pi l\sigma_s}\right)\left(\frac{x}{x^2 + d^2}\right) \tag{9}$$

$$|E_a| = \left(\frac{2V}{\ln\left(\frac{2h}{a}\right)}\right)\left(\frac{h}{h^2 + x^2}\right) \tag{10}$$

where B	=	magnetic flux density	V	=	voltage on antenna wire
E_{e1}	=	induced earth electric field	a	=	radius of antenna wire
E_{e2}	=	conducted earth electric field	l	=	ground wire length
E_a	=	air electric field	d	=	depth of buried ground wire
I	=	antenna or ground wire current	σ_B	=	bulk earth conductivity
μ_o	=	magnetic permeability in free space	σ_s	=	surface earth conductivity
h	=	height of antenna wire	j	=	$\sqrt{-1}$
x	=	horizontal distance to antenna wire	f	=	frequency of antenna current

The equations assume that the distance of the measurement point from the antenna or ground wire is small relative to the length of the antenna or ground wire, and they are valid for all treatment site measurement points. Although EM fields at the much more distant control sites are also dependent on the same variables, Equations 7-10 are not accurate predictors of the EM field intensities at control sites.

4.3.1 Spatial Field Variability

4.3.1.1 Predicted Sources of Spatial Variation. Of the four field components indicated, magnetic flux density is dependent on the fewest variables. It is described by Equation 7, which is valid for the magnetic flux density in both the air and the earth. This equation may also be used to predict the magnetic flux density resulting from ground wire currents by replacing "h" with "d." The magnetic flux density at any point is dependent only on antenna current and distance from the antenna. Its magnitude is inversely proportional to the separation distance from the antenna or ground wire.

The total electric field in the earth at any point is the sum of that induced by the magnetic field and that generated by current conducted from the buried ground terminals. Equations 8 and 9 illustrate the difference in the earth electric field near antenna ROWs and ground terminals, respectively. Spatially, the earth electric field near an antenna ROW decreases logarithmically with separation from the antenna, assuming homogeneous earth conductivity. The spatial variability near a buried ground wire is somewhat more complicated. Directly above the ground wire is a null in the earth electric field explained by a change in polarity as currents bleed off the wire in opposite directions. Field intensities then rise sharply, reaching a peak at a distance roughly equal to the wire burial depth (nominally 8 feet) after which the field decreases in inverse proportion to the distance from the wire. Such a pattern also assumes a homogeneous earth conductivity. Deviations from the earth electric field intensity levels modeled by Equations 8 and 9 are expected because of anomalies in the earth conductivity caused by large rocks, roots, elevation changes, or soil moisture variability among other factors.

In an ROW or a clearing near the antenna the air electric field is well modeled by Equation 10. It decreases with the square of the distance from the antenna. Deviations from this pattern are not expected, provided that surrounding vegetation is low enough so as not to shield the field. At other locations where vegetation and trees shield the air electric field described by Equation 10, an electric field may be set up in the air as a by-product of the electric field in the earth. In these cases, potential differences associated with the earth electric field are translated to the air through objects such as trees and other vegetation. Spatial variability of this air electric field is expected to be subject to the same factors as the earth electric field that creates it.

4.3.1.2 Measured Spatial Variability--EM Field Profiles. EM field profiles were first characterized in 1987 at bird nest box study sites in an attempt to characterize the EM fields across these large area

study sites. The profiles are generated from a series of measurements at prescribed distances along a line perpendicular to the antenna wire. These measurements have been performed annually since 1987, and resulting profiles for all years are presented in Figures A-17 through A-37. They provide excellent examples of the decreases in the magnetic, earth, and air electric fields with increasing distance from an antenna ROW. The magnetic flux density and air electric field intensity in cleared areas are essentially as predicted. Site anomalies affecting the earth conductivity result in peculiarities in the earth electric fields, such as rises in the field intensity level with increasing distance from the antenna and other unusual decay patterns.

Similar annual profile characterizations were begun at the upland flora and soil microflora antenna and ground study sites in 1989. In 1991, measurements were performed for conditions of NS antenna operation only, as well as simultaneous operation of both antennas. Profiles of the earth electric field were also constructed from averages of regular measurements in 1991 at fixed earth electric field probes and from data logger monitoring systems established at these sites in 1991. The profiles for these sites are presented here for discussion of events specific to 1991, as well as spatial EM field phenomena representative of these and other sites for all years.

Profiles of the 76 Hz air electric field and magnetic flux density along transects perpendicular to the upland flora antenna and ground ROWs appear in Figures 16 through 19. Each figure has multiple profiles relating to normal operation with both antennas for the years 1989-1991 and one profile for the period of NS antenna operation only in 1991. The historic measurement points that comprise each profile are identified just above the horizontal axis. Measurement points 4T2-26 and 33 through 36 were not established in 1989, and this profile is therefore missing for that year. Discontinuities at zero distance shown in the curves in Figure 16 and less apparent in Figure 18 result from different start locations beneath the antenna wire for the two profiles.

The air electric fields in the pine plantations at both the antenna and ground sites decrease in a uniform fashion with increasing distance from the antenna or ground feed wire. The field profiles for the antenna site pine plantation have decreased slightly each year. This is because the air electric field at this site, which is set up by the potential difference between the antenna wire and ground surface, is being increasingly shielded by the growing pine trees. The same effect is not seen at the ground site because the buried ground wire, which is the main contributor to the air electric field here, creates a potential difference between trees that is less affected by the tree height. At the ground site there is also a dip in the field profiles near the plot center, which occurs in all years. This is caused by an interaction between, and partial cancellation of, the fields produced by the overhead and buried ground wires. The profiles for both sites may be used to provide good estimates of the air electric field intensity at any point in the pine plantations by graphical interpolation, given the distance of the point from the antenna or ground wires.

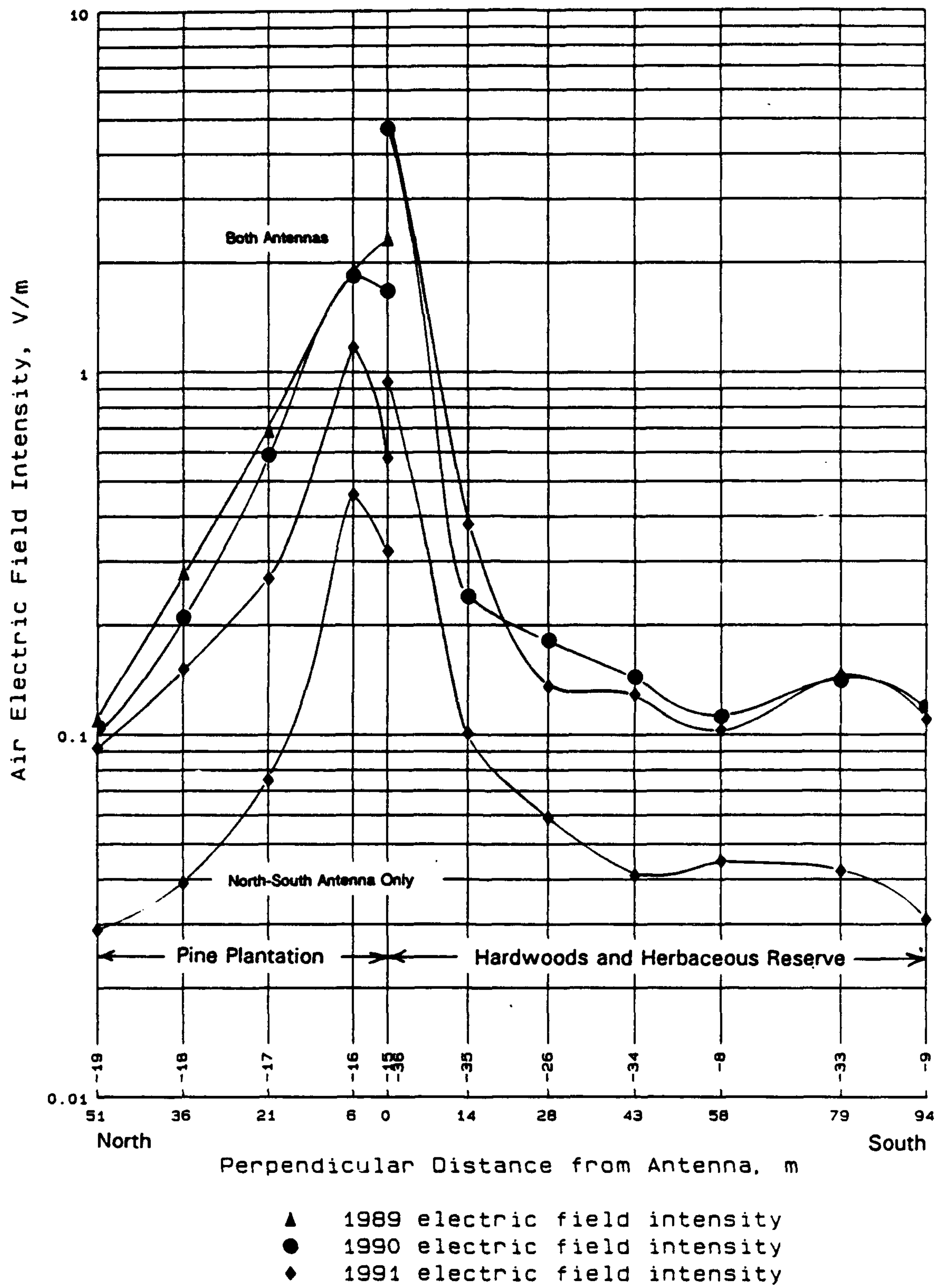


FIGURE 16. 76 Hz AIR ELECTRIC FIELD PROFILES, MARTELL'S LAKE (OVERHEAD): ML; 4T2-8, 9, 15-19, 26, 33-36.

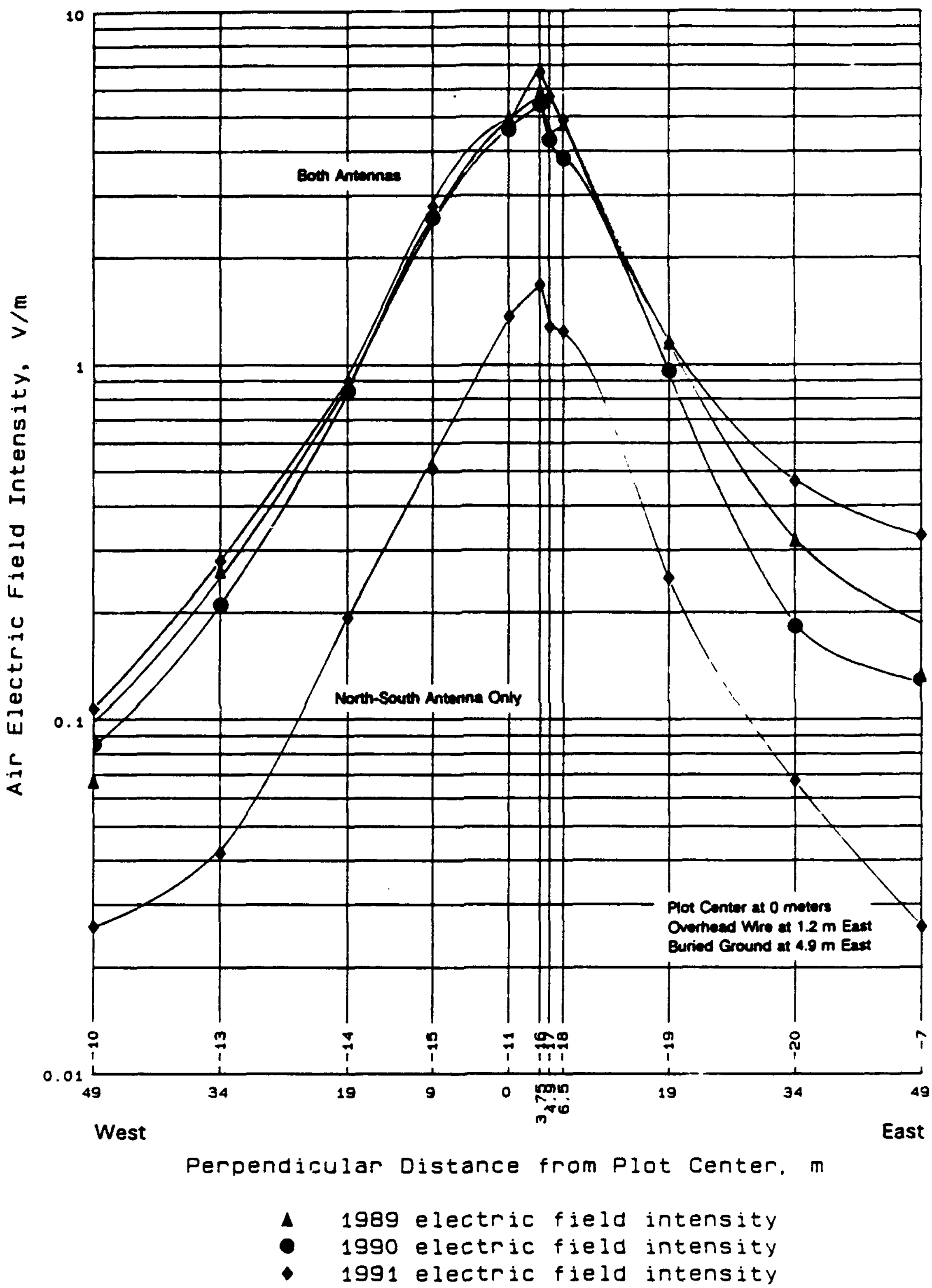


FIGURE 17. 76 Hz AIR ELECTRIC FIELD PROFILES, MARTELL'S LAKE (BURIED): EP; 4T4-7, 10, 11, 13-20.

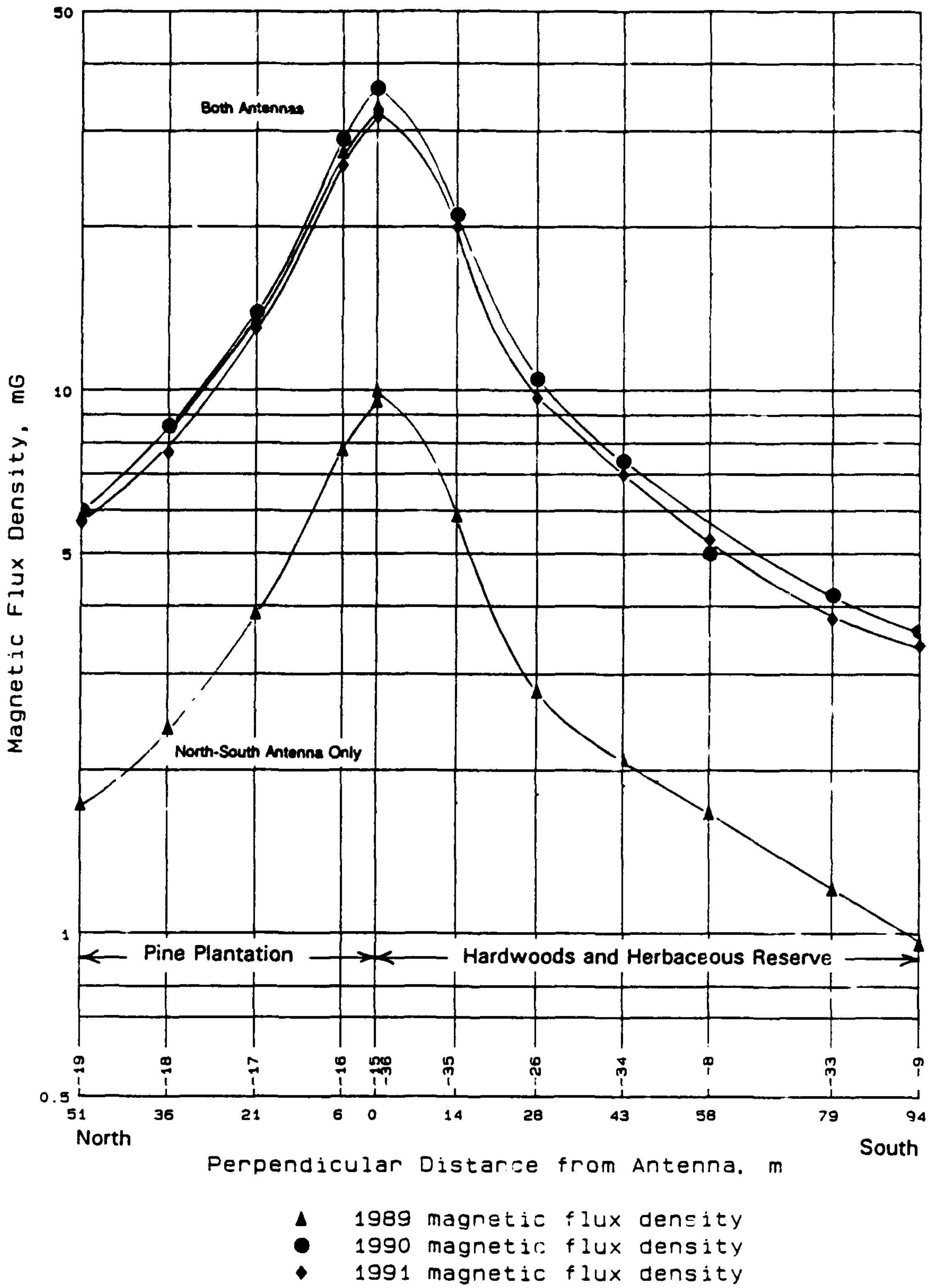


FIGURE 18. 76 Hz MAGNETIC FLUX DENSITY PROFILES, MARTELL'S LAKE (OVERHEAD)· ML; 4T2-8, 9, 15-19, 26, 33-36.

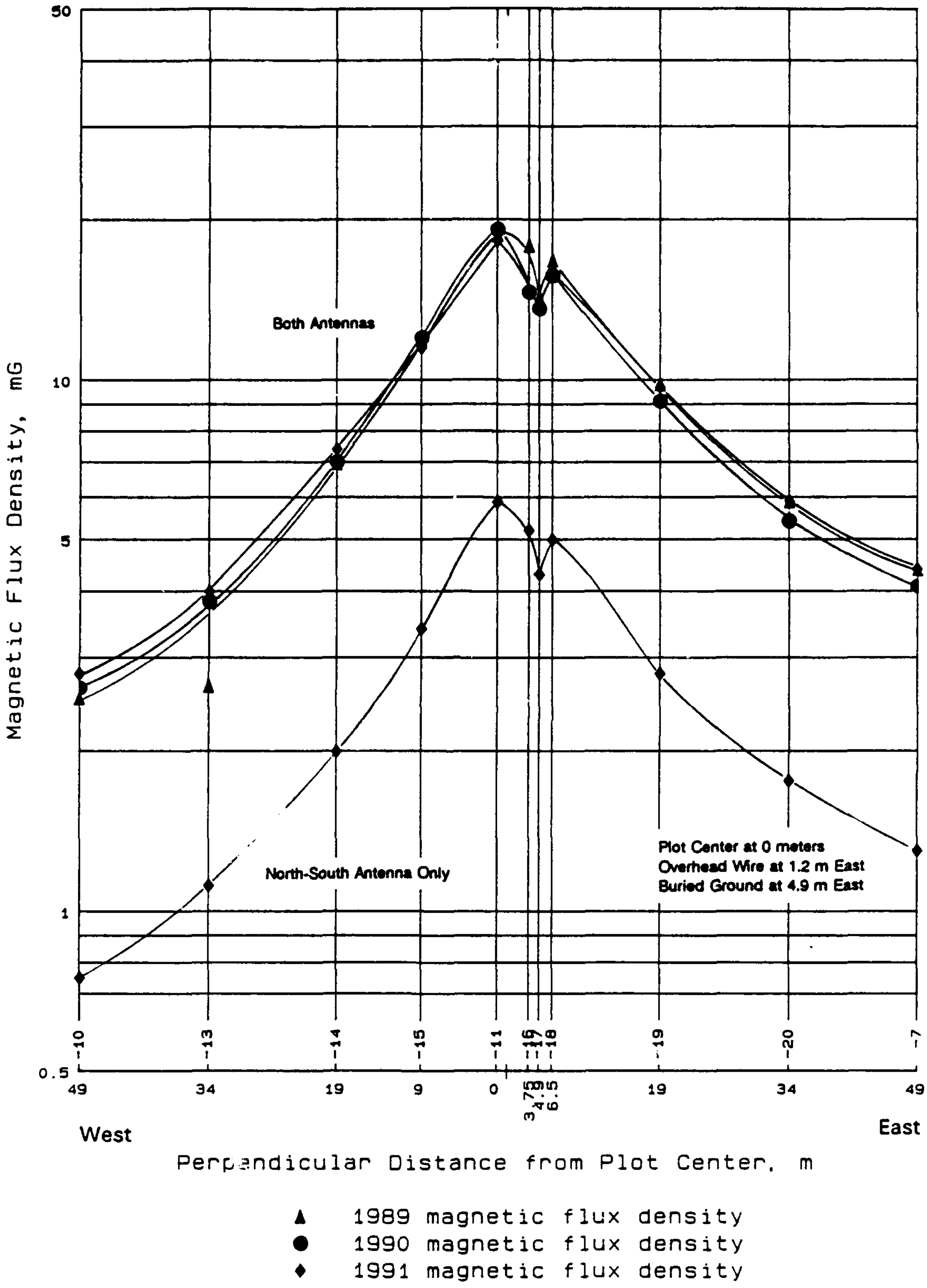


FIGURE 19. 76 Hz MAGNETIC FLUX DENSITY PROFILES, MARTELL'S LAKE (BURIED): EP; 4T4-7, 10, 11, 13-20.

The air electric field profile for the pole stand and herbaceous reserve plots is not as uniform as that for the pine plantations. The air electric field, normally set up by the potential difference between the antenna wire and the earth, is shielded by the tall trees at these plots. The air electric fields which do appear at these plots are the by-product of the earth electric field and are subject to the same variables as the earth electric field. Because these fields vary unpredictably across the pole stand and herbaceous reserve plots, the historic profile data can only be used to bound expected values at these plots. It cannot be used to predict field intensity levels at other points on the plots.

The magnetic flux density is dependent only on the distance of the measurement point from the source. The profiles for this field are therefore the most predictable and stable of those measured. As shown in Figures 18 and 19, the fields decrease uniformly with increasing distance from their sources. At the ground site, a dip in the magnetic flux density profile near the plot center, similar to that seen for the air electric field, occurs in all years. This, again, is caused by an interaction between and partial cancellation of the fields generated by the overhead and buried ground wires. These profiles may be used to estimate the magnetic flux density at any point at the treatment sites with very good accuracy.

Earth electric field profile data for the upland flora and soil microflora treatment study sites were obtained from three sources in 1991:

- annual measurements
- periodic measurements at fixed probes
- continuous measurements by data logger monitoring systems.

Statistical summaries of the 1991 earth electric field data from the data loggers and fixed probes are presented in Tables 7 and 8, together with corresponding annual measurements. Table 7 summarizes data for the period 13 July-23 December when both antennas were operating. Table 8 covers the period 29 May-11 July when only the NS antenna was operating. Most fixed probe locations listed in these tables were not established until 16 August and therefore do not have data presented for them in Table 8.

Both tables show good agreement between the three measurement sets. The means at the fixed probe locations, which employ the same electrodes as the data loggers, are typically within one standard deviation of the logger measurement means. The annual measurement values also closely track the logger and fixed probe means, even though these measurements are taken with a separate probe at a slightly offset position from the fixed probe.

The means of the fixed probe and data logger measurements along with the annual earth electric field intensity measurements listed in Tables 7 and 8 are plotted as electric field profiles in Figures 20 and 21. Each figure has one set of profiles for normal operation with both antennas and one set for NS antenna operation only. Error bars (± 1 standard deviation) are plotted for the data logger mean values. Again, discontinuities at zero distance in the curves in Figure 20 result from different start locations beneath the antenna wire for the two profiles.

TABLE 7. 1991 EARTH ELECTRIC FIELD STATISTICAL SUMMARY FOR THE PERIOD 13 JULY-23 DECEMBER BOTH ANTENNAS ACTIVATED

	Data Logger				Fixed Probe				
Location	No. of Data Points	Mean, mV/m	SD, mV/m	Coeff. of Variab.	No. of Data Points	Mean, mV/m	SD, mV/m	Coeff. of Variab.	Annual, mV/m
				Antenna Site, Hardwood Stand					
4T2-36	2943	136	9.3	0.069	7	137	4.6	0.033	133
4T2-35	3543	154	10.9	0.071	7	162	7.6	0.047	137
4T2-26	3468	220	14.3	0.066	8	210	14.0	0.066	189
4T2-34	3653	108	11.5	0.106	8	110	7.4	0.067	127
4T2-8	3305	138	9.9	0.071	6	141	6.1	0.043	139
4T2-33	3540	113	9.2	0.082	8	120	7.7	0.064	130
4T2-9	926	136	8.3	0.061	4	156	10.0	0.064	121
				Antenna Site, Pine Plantation					
4T2-15	2913	67	9.8	0.145	8	63	2.9	0.046	82
4T2-16	2273	115	16.4	0.142	5	112	7.3	0.065	92
4T2-17	3175	111	10.9	0.099	8	106	7.0	0.066	107
4T2-18	3206	114	13.0	0.114	8	111	4.3	0.039	124
4T2-19	2231	129	18.3	0.142	6	110	7.9	0.072	103
				Ground Site, Pine Plantation					
4T4-7	315	135	16.9	0.126	1	145			101
4T4-20	396	181	19.0	0.105	1	220			200
4T4-19	3222	750	49	0.065	6	770	55	0.072	880
4T4-18	3563	4100	490	0.118	8	4400	270	0.062	4100
4T4-16	3644	3100	480	0.155	8	3300	194	0.058	3300
4T4-15	3255	750	43	0.058	8	760	60	0.079	820
4T4-14	837	260	12.8	0.048	6	240	22	0.095	320
4T4-13	-	-	-	-	2	78	1.5	0.019	59

- = Monitoring system errors; valid data not acquired.

TABLE 8. 1991 EARTH ELECTRIC FIELD STATISTICAL SUMMARY FOR THE PERIOD 29 MAY-11 JULY NORTH-SOUTH ANTENNA ONLY ACTIVATED

Location	Data Logger				Fixed Probe				Annual, mV/m
	No. of Data Points	Mean, mV/m	SD, mV/m	Coeff. of Variab.	No. of Data Points	Mean, mV/m	SD, mV/m	Coeff. of Variab.	
Antenna Site, Hardwood Stand									
4T2-36	456	36	5.9	0.162					44
4T2-35	456	48	6.5	0.135					45
4T2-26	456	59	6.3	0.107	2	65	2.5	0.039	57
4T2-34	456	32	3.3	0.104					36
4T2-8	455	33	3.3	0.100	2	43	0.50	0.012	40
4T2-33	456	33	3.0	0.091					41
4T2-9	442	32	2.9	0.088	2	38	0.50	0.013	40
Antenna Site, Pine Plantation									
4T2-15	-	-	-	-					32
4T2-16	-	-	-	-	2	34	0.50	0.015	33
4T2-17	-	-	-	-					29
4T2-18	-	-	-	-					29
4T2-19	-	-	-	-	2	33	0.0	0.0	31
Ground Site, Pine Plantation									
4T4-7					2	37	0.50	0.014	30
4T4-20	453	50	7.9	0.159					49
4T4-19	453	192	12.0	0.063					196
4T4-18	453	850	109	0.129					1000
4T4-16	453	770	102	0.133					690
4T4-15	453	185	13	0.071					220
4T4-14	453	76	6.2	0.081					59
4T4-13	-	-	-	-					15.2

\- = Monitoring system errors; valid data not acquired.

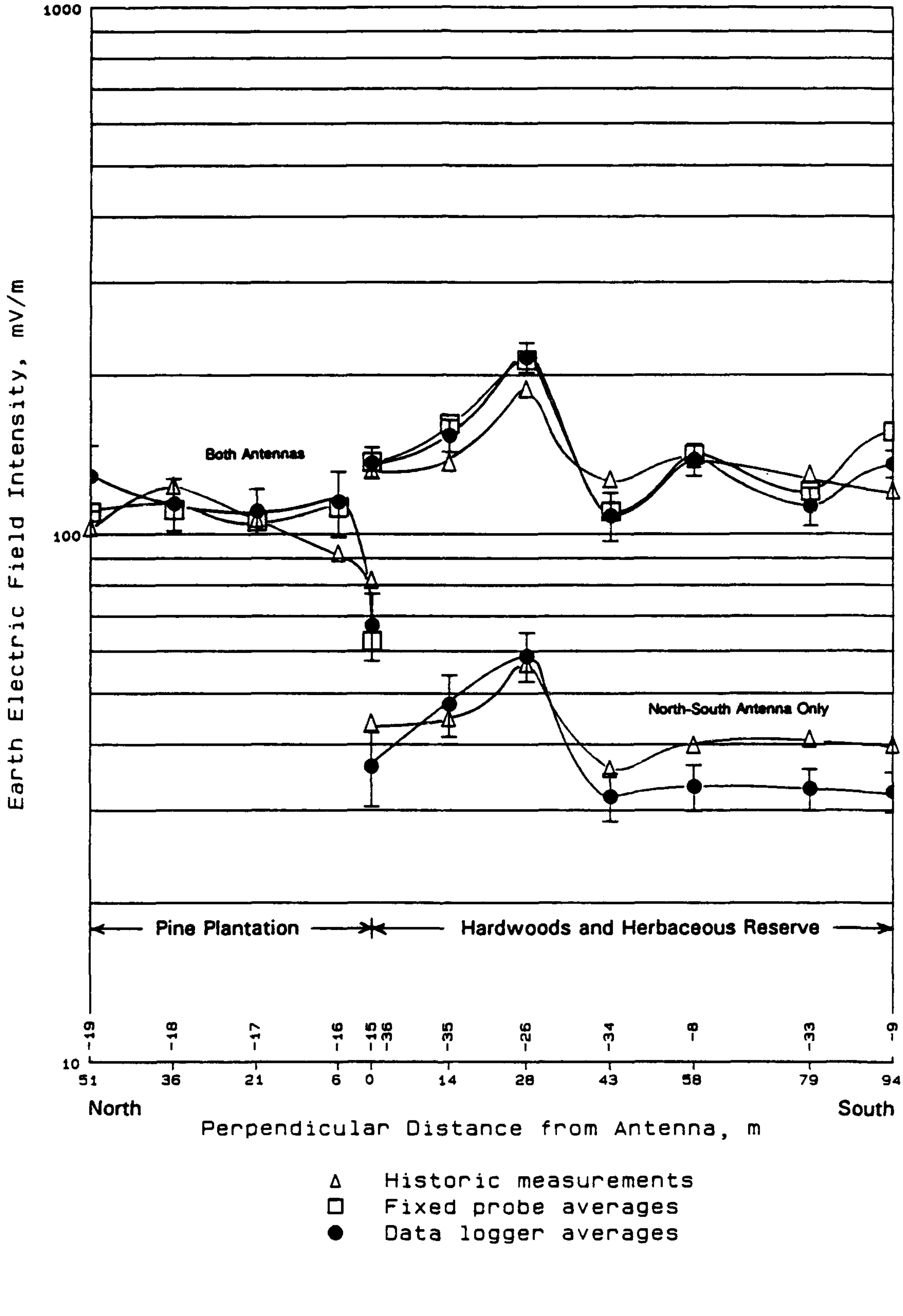


FIGURE 20. COMPARISON OF 76 Hz EARTH ELECTRIC FIELDS AT SITE 4T2. ERROR BARS ARE ±1 SD OF THE LOGGER DATA.

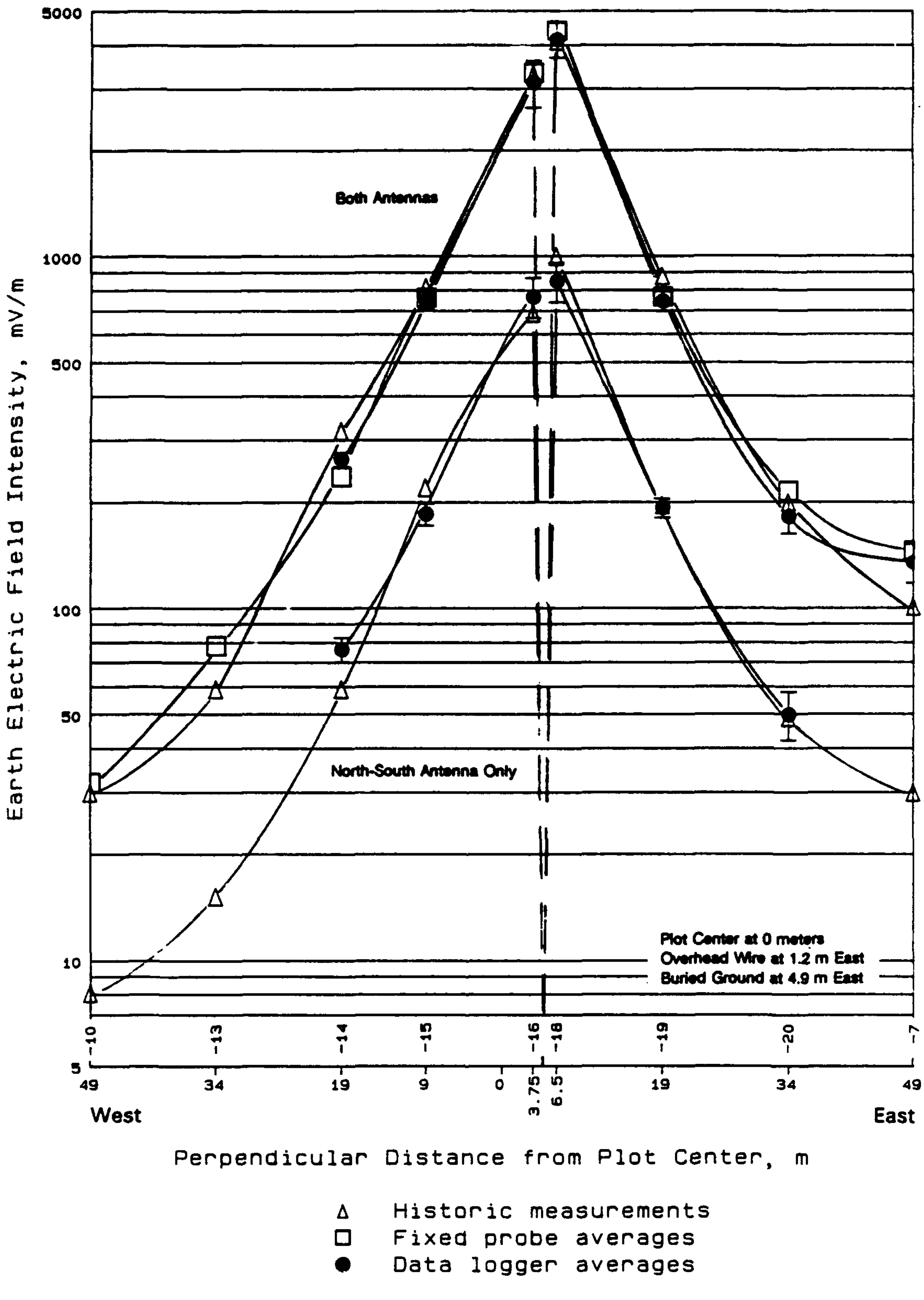


FIGURE 21. COMPARISON OF 76 Hz EARTH ELECTRIC FIELDS AT SITE 4T4. ERROR BARS ARE ±1 SD OF THE LOGGER DATA.

The earth electric field at treatment sites is influenced by several factors, making it very difficult to predict. At this antenna site the field shows both increases and decreases with increasing distance from the antenna. Such irregularities are the result of varying terrain elevations and differences in soil conductivity.

The earth electric field at the ground site has a null over the buried ground wire, with relatively high peaks on both sides of the wire. This is characteristic of the earth electric field near an ELF ground wire and was modeled by Equation 9. The field at the ground site decays much more uniformly than at the antenna site, indicating that the soil conductivity is much more uniform here.

Because the earth electric field behaves unpredictably across these treatment sites, the historic, data logger, and fixed probe data will not provide very accurate estimates of the earth fields at other points at these sites. To improve on these estimates, several earth electric field measurements were taken at these sites in 1990 and used to create contour maps of the field.[8] Results of this effort are presented in Appendix D. It is important to remember that much of the field variability demonstrated by these contour maps results from instrumentation specific to these studies, which is installed on the sites. Variability at non-instrumented study sites will likely be lower.

4.3.1.3 Measured Earth Electric Field vs. Soil Depth. The effects of soil depth on earth electric field intensities may be of importance for ecological studies investigating plants or ground dwelling organisms. In 1991, the principal investigator for the earthworms and soil arthropods study requested such information to examine possible correlations between earth electric field intensities and earthworm affinities for different soil layers. In response, IITRI designed and fabricated special coaxial electrodes to measure the earth electric field in the three soil horizons specified by the principal investigator. The depths specified were 5 cm, 25 cm, and 60 cm. In actuality, the electrode measurement spans were 0-5 cm, 25 $\pm$ 4 cm, and 60 $\pm$ 6 cm in order to provide enough electrode surface area for good soil contact. Pairs of these 1-m-spaced, coaxial electrodes were installed at two locations within each study site (labeled E3 in Figures 11 and 12) and connected to data loggers for continual monitoring.

Graphs of the multidepth electric field measurements are provided in Figures 22, 23, and 24. The electric field and soil temperature data presented are daily averages of the hourly measurements. Air temperatures are the daily max/min and rainfall is the daily total. Initial measurements taken at the time of electrode installation showed no changes in the earth electric field intensity as a function of depth for any of the measurement locations. However, slight differences between levels became apparent within hours of the start of monitoring and persisted. Despite these differences, no consistent trend appears in the relative level of field intensity versus soil depth. What is evident in all three figures is a slight reduction in electric field intensity when the EW antenna is off. Some of the measurement data also seem to show a correlation between heavy rainfall and elevated electric field intensities.

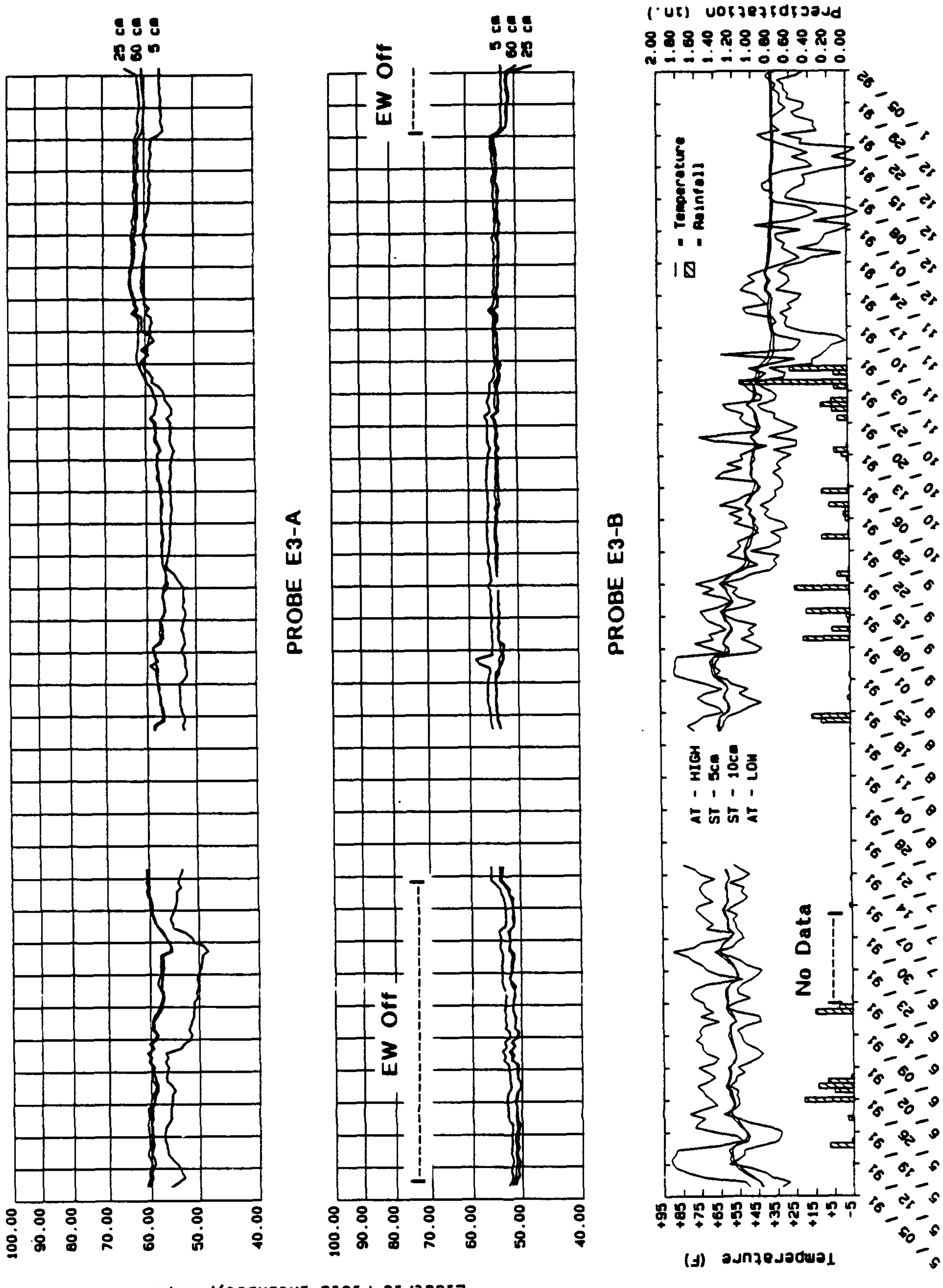


FIGURE 22. TREATMENT SITE 76 Hz ELECTRIC FIELDS VS. SOIL DEPTH-DAILY AVERAGE OF HOURLY MEASUREMENTS.

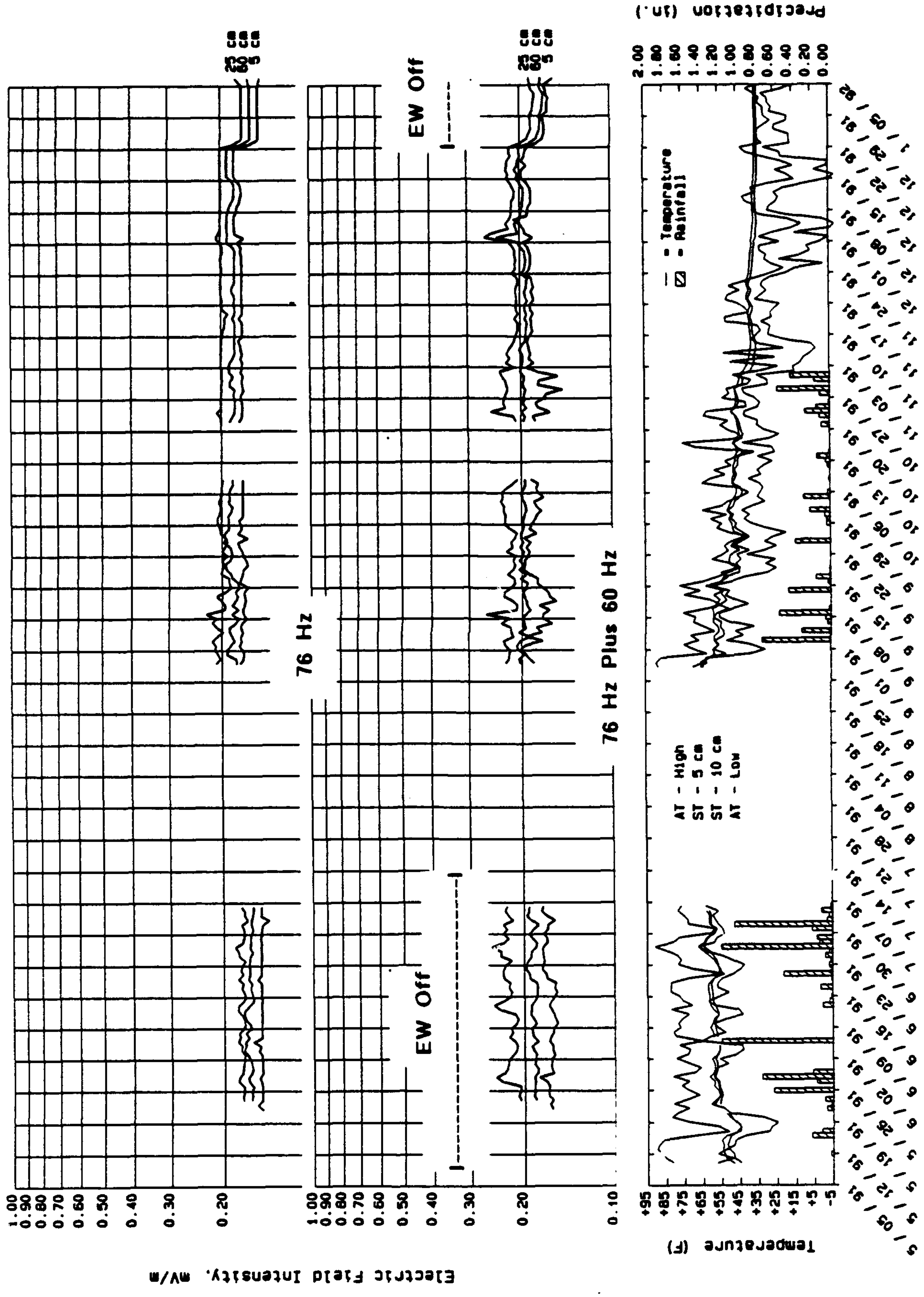


FIGURE 23. CONTROL SITE ELECTRIC FIELDS VS. SOIL DEPTH, PROBE A--DAILY AVERAGE OF HOURLY MEASUREMENTS.

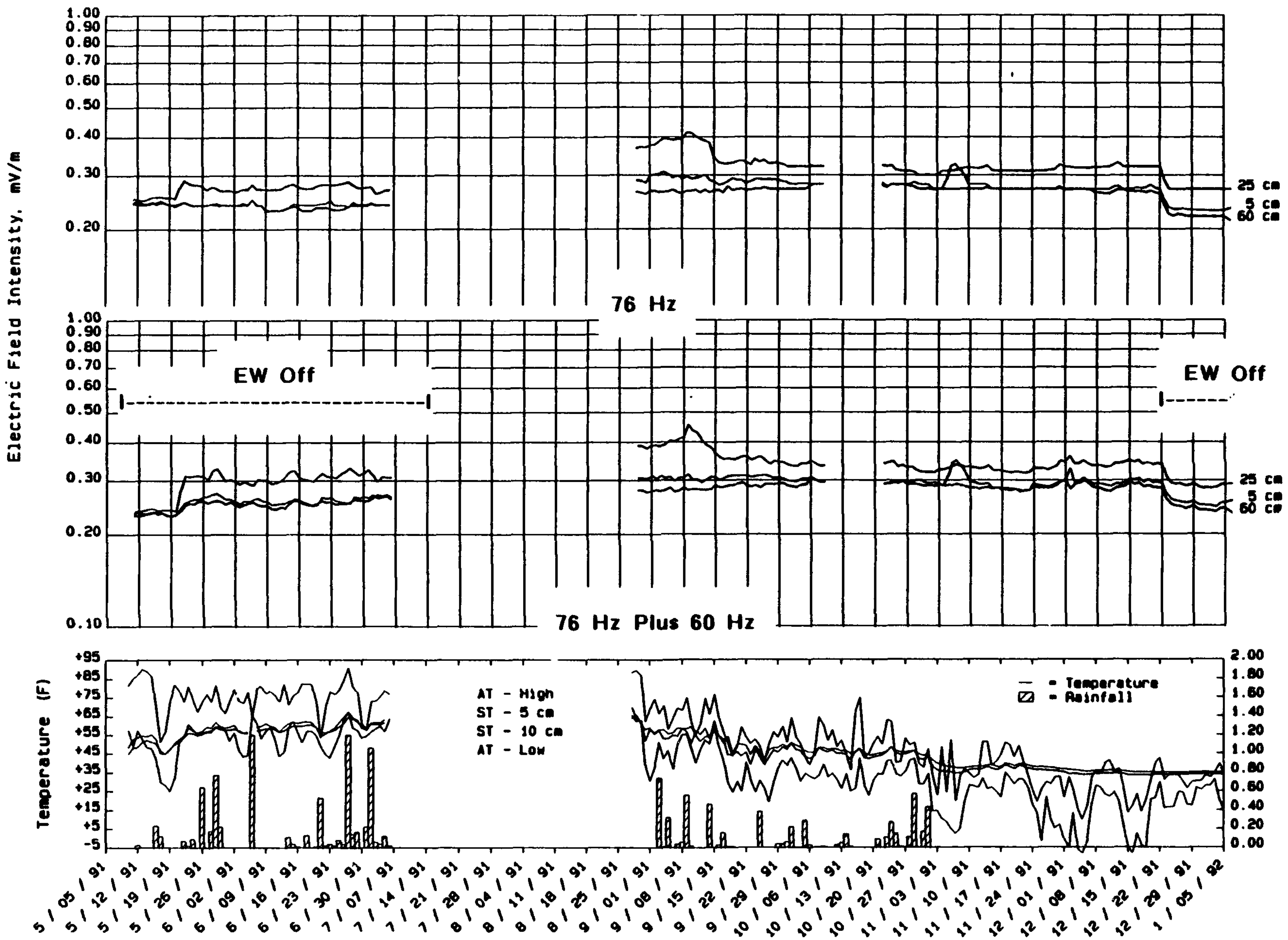


FIGURE 24. CONTROL SITE ELECTRIC FIELDS VS. SOIL DEPTH, PROBE B--DAILY AVERAGE OF HOURLY MEASUREMENTS.

In general, the 76 Hz electric fields at the treatment site are fairly stable over time, especially at the lower soil depths. The surface fields appear somewhat more variable. 60 Hz electric field intensities at the treatment site were too low to be detected when the antenna was on.

At the control site, the 60 Hz field levels are known to be similar in magnitude to the 76 Hz levels (see Tables C-4 and C-7), and dc contribute to the overall field magnitude and variability. This is illustrated in Figures 23 and 24 by the differences in the curves labeled "76 Hz" and those labeled "76 Hz Plus 60 Hz." Although the differences in the curves may not seem large, it must be noted that they are plotted on a log scale. Furthermore, rms voltages at different frequencies do not add linearly, but as the square root of the sum of squares. As an example, the rms sum of a 76 Hz field and a 60 Hz field of half its intensity is only 12% greater than the 76 Hz intensity alone.

4.3.2 Temporal Field Variability

4.3.2.1 Predicted Sources of Temporal Variation. Annual EM field measurements generally have been made in late summer and early fall. Since most biota remain on the study sites throughout the year, the subject of EM field variations over the course of a year is important. Temporal variations related to differences in the operating parameters of the ELF transmitters and to climatic variables such as temperature, rainfall, and soil moisture levels are expected. Mathematical descriptions of the fields given at the beginning of Section 4.3 show the functional relationships of the EM field variables and provide a basis for understanding and predicting temporal variations. Measurements of temporal EM field variations are presented in the following four subsections.

The magnetic flux density is the least variable of EM fields. It is described by Equation 7, which is valid for the magnetic flux density in both the air and the earth. This equation may also be used to predict the magnetic flux density resulting from ground wire currents by replacing "h" with "d." The magnetic flux density at any point is dependent only on antenna current and distance from the antenna. It is not expected to show seasonal variation, because it is not affected by the conductivity of surrounding vegetation and soil and it does not vary with the antenna frequency.

The total earth electric field at any point is the sum of that induced by the magnetic field and that generated by current conducted from the buried ground terminals. Equations 8 and 9 illustrate the differences in the earth electric field near antenna ROWs and ground terminals, respectively, as a function of current, frequency, and soil conductivity. Note that the conducted electric field is dependent on the ground wire current only, while the magnetically induced electric field is dependent on both the antenna current and the frequency. Thus, significant variations in the induced earth electric field are expected with changes in the antenna operating frequency. Electric field intensities for 44 Hz operation should be a little over half the intensity levels induced with 76 Hz operation. Smaller and less obvious changes in field intensity are also expected because of the MSK signal used by the ELF antennas (see Section 1.2).

Although this report generally refers to the MSK signal by its center frequency, the antenna frequency actually shifts between two frequencies 8 Hz apart. This changing frequency will also result in a changing induced electric field intensity.

In Equations 8 and 9, earth conductivity is the only variable that is expected to show a seasonal variation. In both cases, the field intensities are dependent on soil conductivity, which in turn varies with changes in soil moisture and temperature. The two conductivity terms (bulk and surface) are not equivalent, and have different functional relationships within the corresponding electric field equations. The earth electric field near ground terminals is dependent primarily on surface earth conductivity, while bulk earth conductivity determines the electric field near antenna ROWs. The bulk earth conductivity is a weighted average of the surface and deep earth conductivities. Because the deep earth conductivity remains stable throughout the year, the bulk earth conductivity shows less seasonal variation than does the surface earth conductivity.

In addition to these differences in effective conductivity, the earth electric field near ground terminals varies inversely with conductivity, while the earth electric field along antenna ROWs varies in proportion to the natural logarithm of the inverse of the square root of conductivity. Thus, the earth electric field is almost twice as sensitive to changes in conductivity near ground terminals as it is to changes in conductivity along antenna ROWs. This fact, in conjunction with the expected higher variation in surface conductivity, indicates that the greatest seasonal variations in earth electric fields will occur along ground terminal ROWs. Additional earth electric field variability can result if either conductivity term is itself frequency-dependent.

The air electric field in an ROW or a clearing near the antenna is essentially dependent only on the antenna voltage, and the distance to and height of the antenna wire. It should be noted that the antenna voltage is constant for a given antenna current, and there is no frequency-dependent term in Equation 10. The air electric field is also independent of soil conductivities and humidity. Therefore, it is not expected to show climatic-induced variation at unshielded locations throughout the year. However, at other locations where the air electric field is shielded by vegetation and trees, or generated as a by-product of the earth electric field, more seasonal variation is expected as plants lose or grow foliage or as the earth electric field varies. Such variations in the air electric field would be difficult to quantify to any useful degree.

4.3.2.2 Measured Frequency-Related Electric Field Variations. The expected variations in the induced earth electric field caused by antenna frequency changes have, in fact, been observed in measurements made during periods of 44 Hz and 76 Hz antenna operations. Also detectable are the less dramatic electric field variations that are associated with the MSK modulation. The amount of field variation measured during MSK operation (9-10% at 76 Hz, 16-17% at 44 Hz) is consistent with the percent frequency shift of the MSK signal. Similarly, the 44 Hz and 76 Hz field intensity levels are proportional to

the signal center frequency. Throughout 1991, essentially all antenna operations were with a 76 Hz MSK signal. The best examples of measured frequency-related electric field variations, therefore, come from earlier years when multiple frequencies and signal types were used and are well documented in previous reports.[7,11] Frequency variations of concern in 1991 are limited to those associated with MSK signal operation.

4.3.2.3 Fixed Probe Seasonal Measurements. The 1990 contour drawings presented in Appendix D provide for the most accurate earth electric field estimates at the upland flora and soil microflora treatment study sites. They do not, however, provide information on the temporal variation of these field intensities. For this reason, fixed earth electric field probes were installed in 1990 at 40 measurement points at the antenna and ground treatment sites for these studies. This measurement set was expanded in 1991 to include the electrode pairs monitored by data loggers. The fixed probe locations are shown, together with the historic and data logger measurement points, in Figures D-3 and D-4. Fixed probe measurements have been taken twice a month, with the expectation of identifying long-term or seasonal variations at these points. Fixed probe measurements and summary statistics for June 1990 through December 1991 are listed in Tables D-9 through D-12. With few exceptions, the fields at the fixed probes have shown coefficients of variation typically at or below 10%. No consistent reason has been found to explain the few exceptional cases of high variability. They are believed to be related to changes in soil-to-electrode contact impedance and not actually representative of earth electric field variations.

4.3.2.4 Data Logger Seasonal Measurements. Data logger monitoring systems were installed and have been in operation at soil amoeba study sites since 1988. In 1991, six additional data logger systems were installed at the earthworm, upland flora, and aquatic ecosystems study sites for long-term monitoring of earth electric field variability. Measurement parameters for each of the new logger systems are presented in Table 9. The 1991 data for the earthworm study sites as well as the monitoring system layouts have already been presented in Sections 4.2.2 and 4.3.1.3. Summary plots of 1991 logger data for the upland flora and aquatics study sites are presented here. Layout drawings of the three data logger monitoring systems at the upland flora treatment study sites are shown in Figures D-3 and D-4 (Appendix D). The aquatic ecosystems logger monitoring system is diagrammed in this section. Comprehensive plots of the soil amoeba test chamber data logger measurements appear in Appendix F.

Daily averages of the hourly earth electric field intensity measurements at the upland flora and soil microflora logger sites for 1991 are plotted in Figures 25 through 27. Weather-related parameters that might be expected to impact the electric field intensity levels are on a separate grid below the main plot. The soil temperatures presented were taken by the IITRI data loggers, while the air temperature and rainfall data are from the study researcher's ambient monitoring system (referred to by their affiliation--Michigan Technological University, MTU). The source of the MTU weather data is noted parenthetically in the legend.

TABLE 9. 1991 DATA LOGGER MEASUREMENT PARAMETERS
Earthworms, Upland Flora, and Aquatics Study Sites

	Data Logger Site Identification*					
Measurement Parameter	3C5	3T2	4T2H	4T2P	4T4	5T2
Earth Electric Field (Surface)	•	•	•	•	•	•
Earth Electric Field (3-Depth)	•	•				
Incubation Bag Electric Field	•	•				
Data Logger Case Temperature	•	•	•	•	•	•
Air Temperature	•	•	•	•	•	•
Soil Temperature (5 cm)	•	•				
Soil Temperature (10 cm)	•	•	•	•	•	•
Rainfall	•	•				

*3C5 = earthworms control site.
3T2 = earthworms treatment site.
4T2H = upland flora antenna site, hardwood stand.
4T2P = upland flora antenna site, pine plantation.
4T4 = upland flora ground site, pine plantation.
5T2 = aquatic ecosystems treatment site.

An "A" or "G" is used to designate the antenna or ground site, and a "P" or "H" is used to designate pine plantation or hardwood stand.

Two major shifts in the electric field intensity levels can be seen in Figures 25 through 27. The low field levels prior to 12 July and following 23 December correspond to periods when the EW antenna was shut down. As previously discussed, shutdown of the EW antenna reduced the EM field levels by about a factor of 3. The graphs also show several gaps in the electric field data. These are not periods when the transmitters were off. Rather, they reflect data lost as a result of data logger or electrode failures or by procedure errors made when offloading the data from the logger computers. At the ground site system, measurements from three electrode sets (4T4-7, 14, 20) were confounded by the data logger input protection devices. The problem began when the EW antenna came back on line on 13 July, but was not discovered and corrected until the fall.

The daily average electric field data shown in Figures 25-27 increase slightly for most probes from the summer to winter months. This is caused by an increasing resistivity of the soil with decreasing temperatures and by electrolyte changes of the freezing soil. Monthly electric field averages for each logger probe at these sites are given in Table 10. This table indicates that earth electric field intensities increased at all probe locations for which data were taken between June/July and late December for NS antenna operation. Likewise, electric field intensities increased at most probe sites during operation of

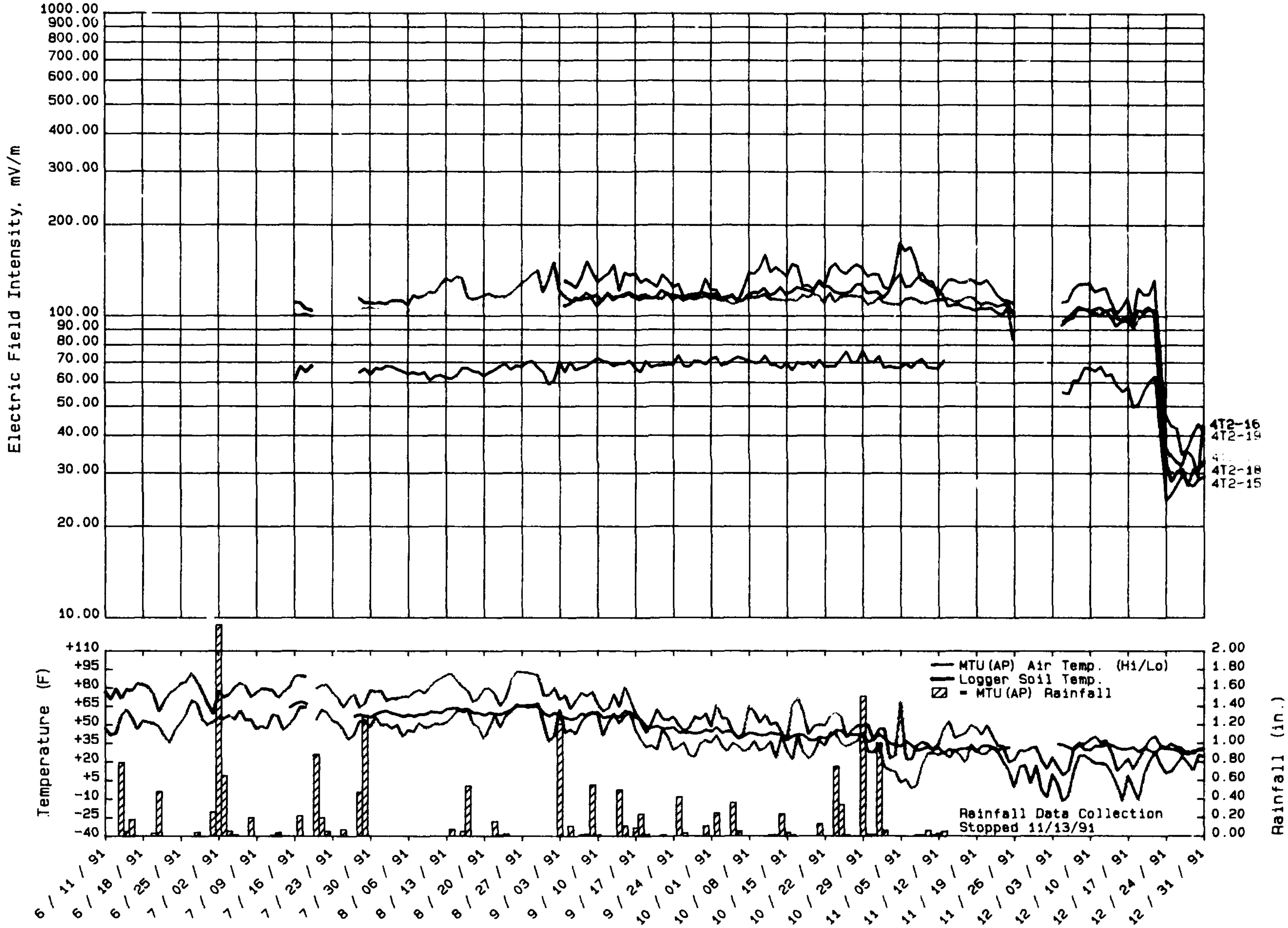


FIGURE 25. DAILY AVERAGE EARTH ELECTRIC FIELD INTENSITIES AT THE ANTENNA SITE, PINE PLANTATION: 4T2-19, 18, 17, 16, 15.

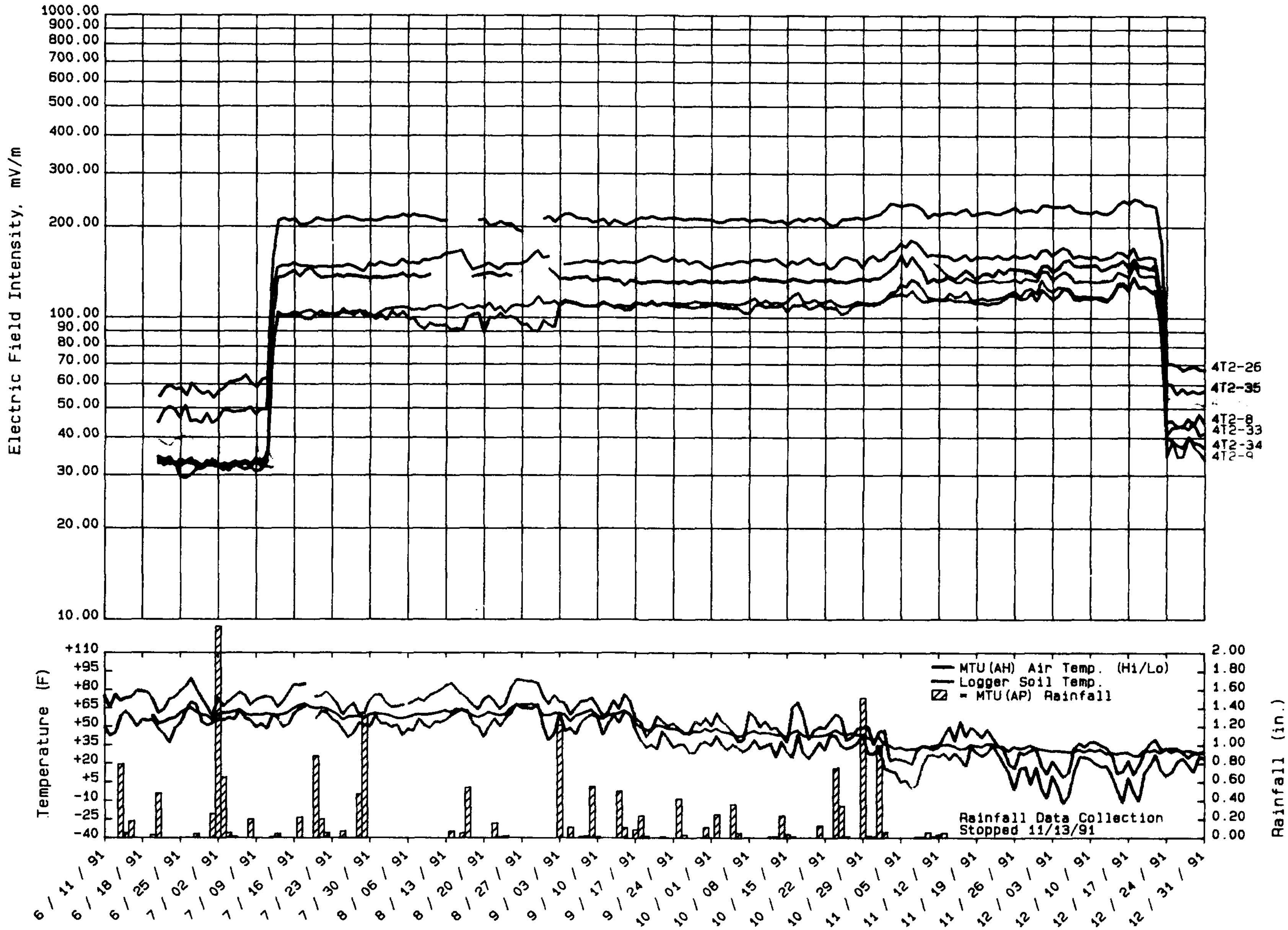


FIGURE 26. DAILY AVERAGE EARTH ELECTRIC FIELD INTENSITIES AT THE ANTENNA SITE, HARDWOOD STAND: 4T2-9, 33, 8, 34, 26, 35, 36.

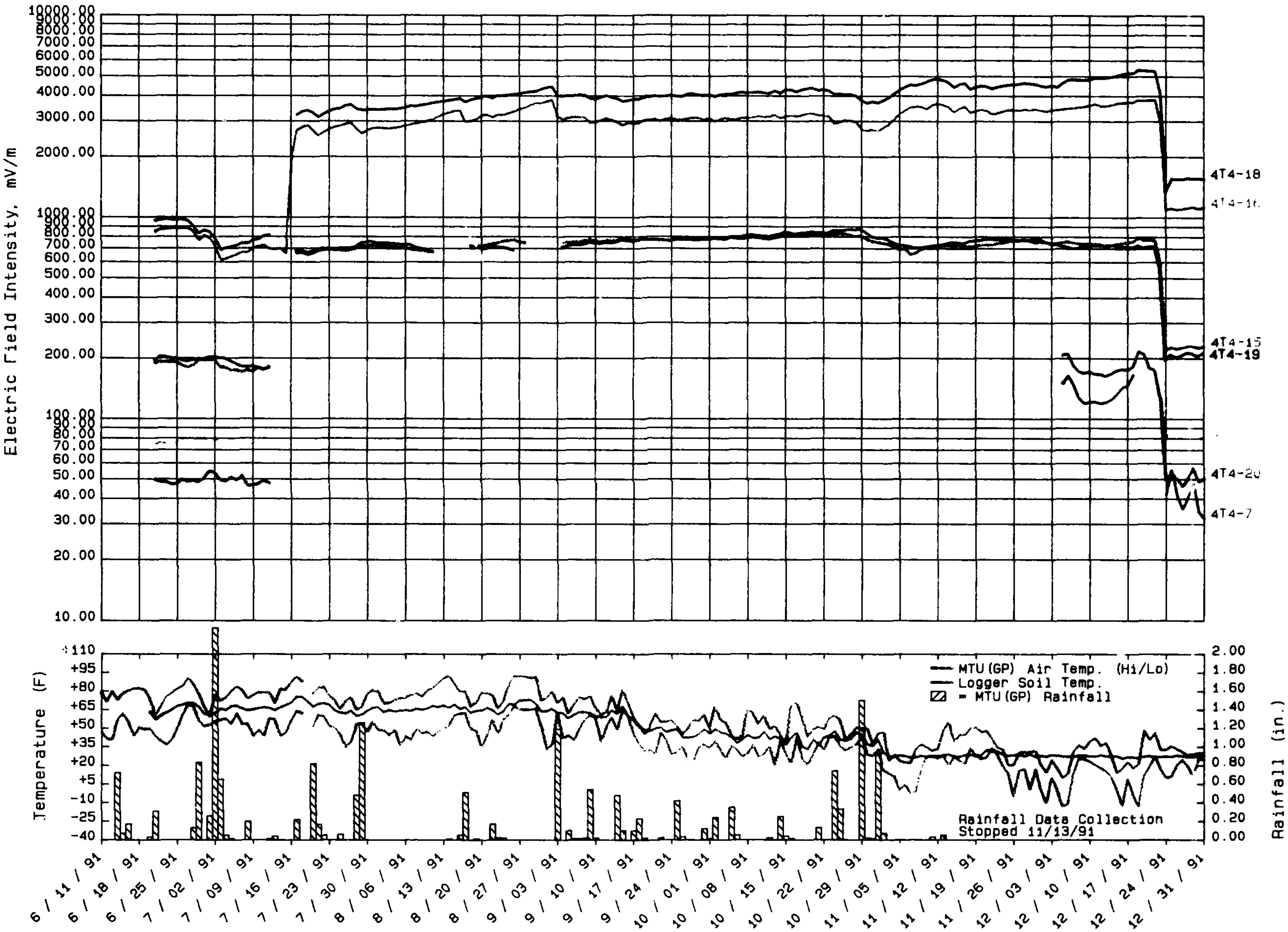


FIGURE 27. DAILY AVERAGE EARTH ELECTRIC FIELD INTENSITIES AT THE GROUND SITE, PINE PLANTATION: 4T4-7, 20, 19, 18, 16, 15, 14.

TABLE 10. 1991 76 Hz EARTH ELECTRIC FIELD INTENSITY AVERAGES (mV/m)
Upland Flora and Soil Microflora Studies Data Logger Measurement

	NS Antenna Only		Both Antennas						NS
Location	Jun 20-30	Jul 1-11	Jul 13-31	Aug 1-31	Sep 1-30	Oct 1-31	Nov 1-30	Dec 1-22	Dec 24-31
Antenna Site/Hardwood Stand									
4T2-9	33 (8.5%)	32 (9.1%)	-	-	-	-	135 (6.6%)	136 (5.6%)	37 (17.3%)
4T2-33	33 (9.1%)	33 (9.1%)	103 (6.9%)	108 (5.7%)	111 (3.8%)	112 (5.4%)	119 (6.9%)	122 (7.5%)	43 (17.9%)
4T2-8	33 (10.6%)	33 (9.7%)	138 (5.3%)	138 (4.5%)	133 (4.7%)	133 (3.8%)	142 (8.2%)	149 (6.6%)	45 (15.3%)
4T2-34	32 (10.9%)	32 (10.0%)	102 (7.4%)	97 (11.6%)	109 (7.1%)	108 (7.6%)	115 (5.7%)	121 (7.8%)	38 (19.2%)
4T2-26	57 (10.2%)	60 (10.7%)	210 (3.3%)	210 (4.8%)	210 (5.5%)	210 (6.6%)	230 (5.4%)	230 (4.4%)	68 (8.4%)
4T2-35	47 (14.0%)	48 (13.1%)	146 (5.1%)	152 (6.3%)	152 (5.7%)	151 (7.2%)	160 (6.6%)	160 (6.2%)	57 (10.9%)
4T2-36	38 (16.3%)	34 (14.4%)	136 (7.4%)	142 (8.7%)	135 (4.9%)	132 (5.4%)	137 (6.7%)	142 (6.4%)	53 (13.2%)
Antenna Site/Pine Plantation									
4T2-19	-	-	-	-	131 (13.5%)	134 (15.7%)	127 (10.2%)	118 (12.7%)	41 (26%)
4T2-18	-	-	111 (10.5%)	120 (11.3%)	118 (11.9%)	114 (9.0%)	112 (8.7%)	102 (9.1%)	30 (30%)
4T2-17	-	-	104 (7.0%)	107 (8.0%)	115 (8.5%)	116 (8.6%)	113 (8.9%)	100 (9.6%)	32 (33%)
4T2-16	-	-	-	-	15 (9.0%)	120 (9.1%)	120 (19.2%)	100 (10.2%)	34 (29%)
4T2-15	-	-	5 (11.5%)	6 (11.7%)	69 (13.3%)	71 (14.7%)	69 (13.6%)	61 (17.1%)	28 (31%)
Ground Site/Pine Plantation									
4T4-7	-	-	-	-	-	-	-	135 (12.5%)	42 (31%)
4T4-20	49 (15.3%)	50 (16.6%)	-	-	-	-	-	181 (10.5%)	51 (22%)
4T4-19	196 (4.2%)	188 (7.3%)	700 (4.3%)	710 (3.1%)	750 (3.2%)	820 (3.7%)	740 (3.8%)	710 (2.8%)	210 (6.4%)
4T4-18	940 (6.2%)	750 (7.2%)	3400 (4.2%)	3800 (7.1%)	4000 (4.2%)	4100 (4.3%)	4500 (6.4%)	4900 (6.1%)	1550 (8.0%)
4T4-16	850 (5.3%)	680 (8.7%)	2400 (3.4%)	3100 (9.0%)	3100 (7.4%)	3100 (5.1%)	3400 (8.2%)	3600 (4.4%)	1110 (3.6%)
4T4-15	190 (5.3%)	180 (7.7%)	690 (4.1%)	720 (4.0%)	770 (1.9%)	800 (2.9%)	730 (4.7%)	750 (2.4%)	230 (3.6%)
4T4-14	77 (7.8%)	76 (8.3%)	-	-	-	-	260 (4.8%)	270 (4.7%)	84 (13.0%)
4T4-13	-	-	-	-	-	-	-	-	-

Percent variability (mean/SD x (100%)) is given below each of the electric field averages.
- = Monitoring system errors; valid data not acquired.

both antennas over the period from late July and early December. The seasonal field increases over these periods were typically between 10 and 30%. However, an increase as great as 65% occurred at probe 4T4-18 near the buried ground wire.

Figure 28 shows the layout of the data logger monitoring system at the aquatic ecosystems treatment study site. Daily averages of the earth electric field intensities measured at the four riverbed probe locations, the daily high and low air temperatures, and the hourly riverbed temperature measured by the data logger in 1991 are plotted in Figure 29. This figure indicates a 10%-20% temporal variation of the earth electric field intensities at each of the four measurement locations. The pattern of variation is similar at all these locations and is most likely attributable to water conductivity changes. Similar temporal variations in the earth electric field are expected at the other aquatics study sites, assuming similar changes in water conductivity.

Also plotted in Figure 29 is the daily rainfall, as measured at the upland flora study site, which is about 10 miles north of the aquatics treatment site. A possible correlation can be seen between these rainfall data and the electric field data. That is, increases in the electric field intensity levels follow rainfall activity. Although the data are not sufficient to draw a firm conclusion, rainfall will certainly lower water ion concentrations (conductivity) and thus raise electric field intensity levels. Other data on the relationships between area rainfalls, local water flow rates, and ion concentrations would be needed to validate the correlation.

4.3.2.5 Data Logger Measured Diurnal Variation. All hourly measurement data from the upland flora study sites were also examined for diurnal variations. Such variations were most apparent near the buried ground wire and are illustrated in the hourly data presented in Figure 30. To clarify the diurnal pattern, the data plotted in this figure were averaged by hour of day for the 28-day period. The hourly averages are plotted in Figure 31. A clear peak in the average field intensity is visible at 8:00 a.m. and a null at 8:00 p.m. for this probe and time period. The daily variation is about 3.5%.

Similar analyses were done for several other probes at both the antenna and ground sites for this study. Although diurnal variations were not identified for all locations and/or time periods, they were observed with some regularity at both sites. When present, diurnal variations were typically less than 5%.

4.4 Transmitter Operations--Analysis and Data Base

4.4.1 Operating Log Data Base

In order to calculate the EM exposure regimes, study investigators must have both field intensity measurements at the study sites and data on the operating times of the antennas. Field intensity measurements were discussed in Section 3, and data tables are presented in Appendixes A through G. Data on antenna operating conditions are provided to IITRI by the Navy's Submarine Communications Project Office. These data include changes in the operating frequency, modulation, power, and phasing

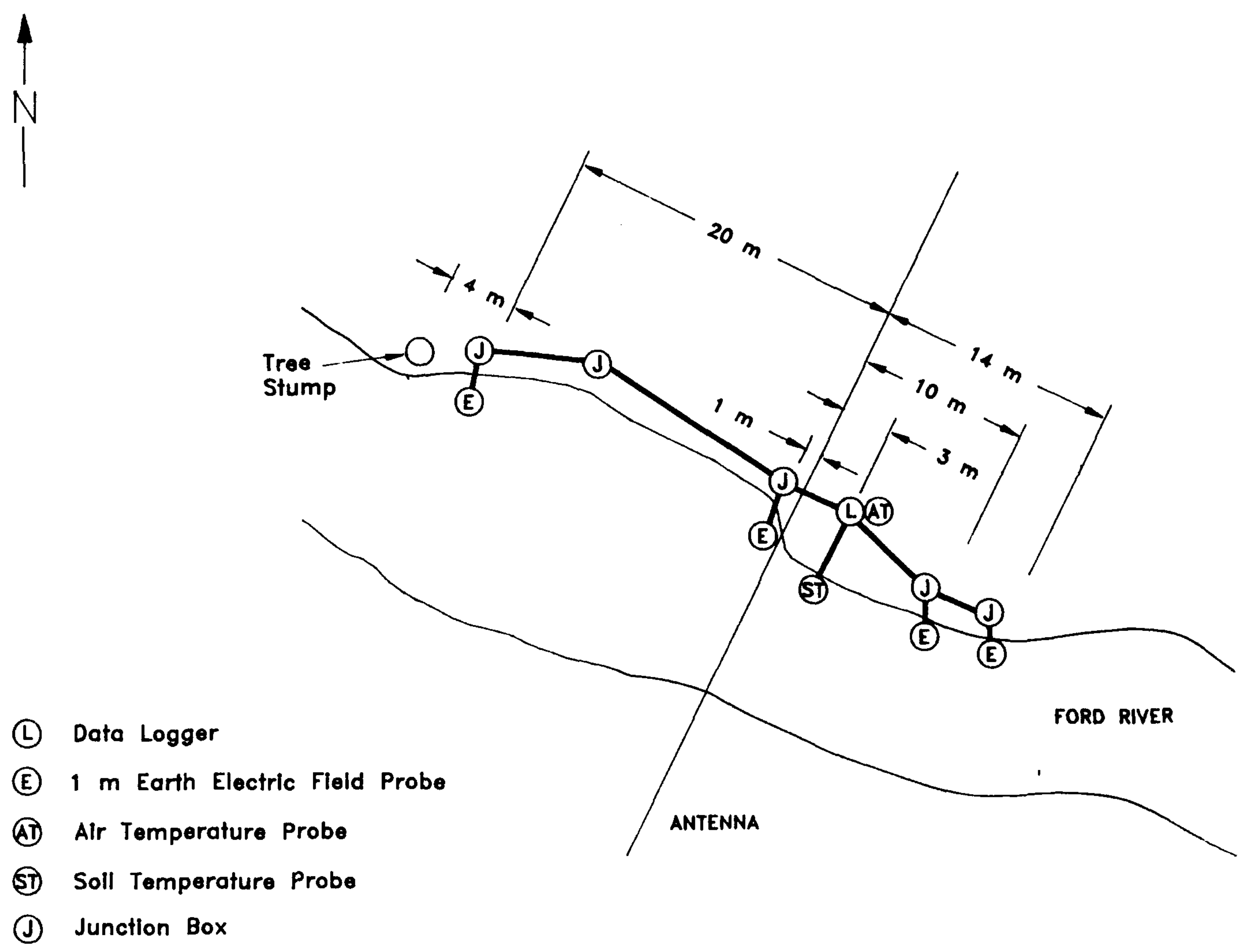


FIGURE 28. DATA LOGGER MONITORING SYSTEM AT FORD EXPERIMENTAL SITE 5T2.

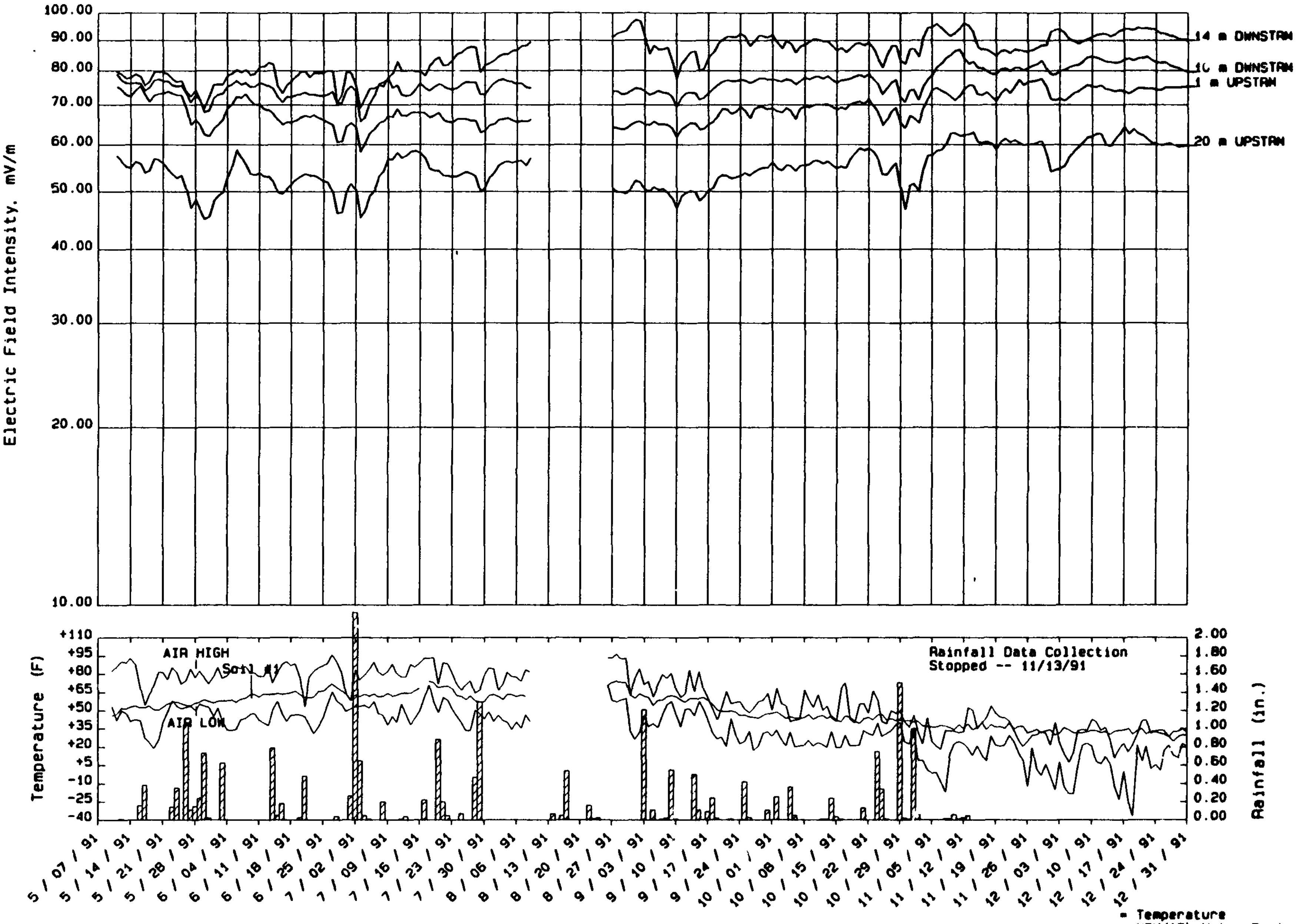


FIGURE 29. 76 Hz DAILY AVERAGE EARTH ELECTRIC FIELD DATA AT SITE 5T2.

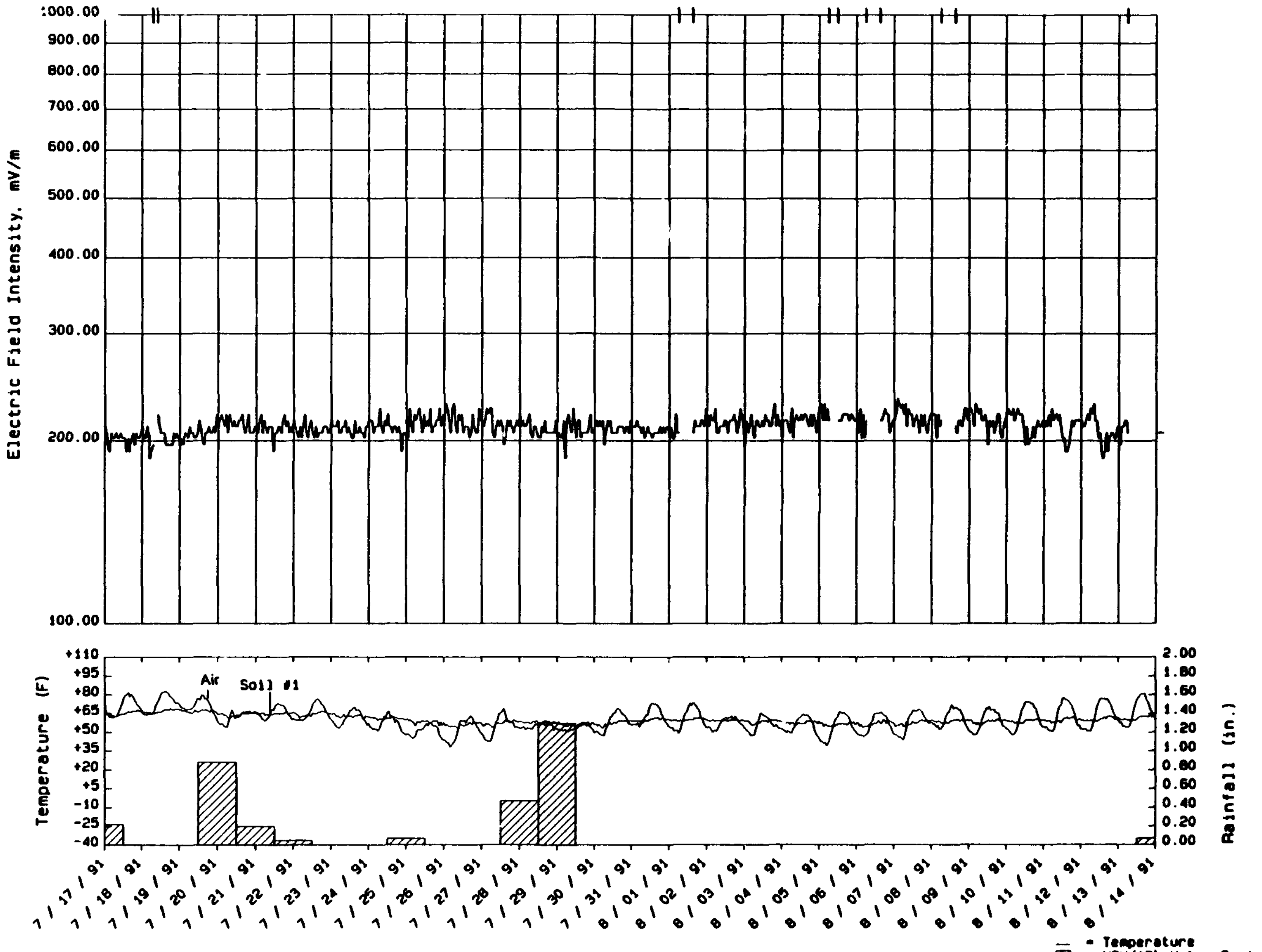


FIGURE 30. HOURLY EARTH ELECTRIC FIELD INTENSITIES AT THE ANTENNA HARDWOOD STAND: MEASUREMENT POINT 4T2-26.

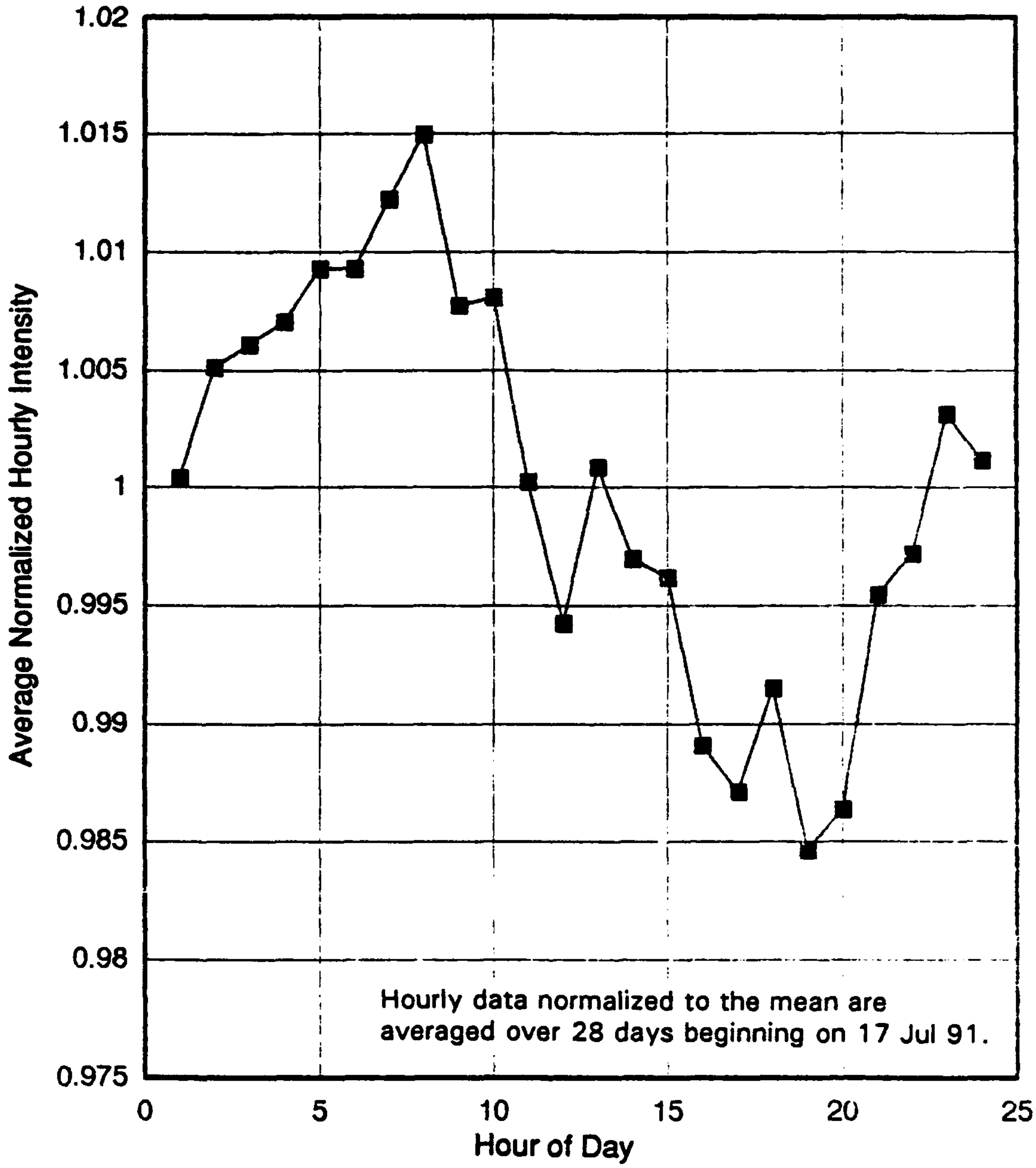


FIGURE 31. EARTH ELECTRIC FIELD DIURNAL CYCLE AT THE GROUND SITE PINE PLANTATION: MEASUREMENT POINT 4T4-18.

for each antenna element. This information is entered into a computer-based spreadsheet that allows the generation of operating condition summaries in both graphic and tabular form. Graphic summaries for the NRTF-Republic are presented in this section; more detailed tabular summaries appear in Appendix J. IITRI provides the data bases to the study investigators on request.

4.4.2 Summary of NRTF-Republic Operations, 1986-1991

The NRTF-Republic has gone through several stages of development. These stages are marked by changes in the operating times, currents, and antenna element configurations. The antenna elements at the NRTF-Republic were first energized in March 1986. Initial tests used a low-current (4, 6, or 10 amperes) unmodulated signal, and the antenna elements were operated individually. In 1987, antenna currents were increased to 15 amperes, and the NEW and SEW antenna elements were permanently connected in parallel, constituting the EW antenna. Antenna currents were increased to 75 amperes during 1988. In May 1989, currents were increased to full power (150 amperes), the NS and EW antennas were operated simultaneously, and a modulated signal was used. Operating times increased dramatically as the NRTF-Republic became an on-line Naval Communications Facility in the latter half of 1989. Normal full-power operation continued throughout 1990 and 1991, with the exception of the previously given periods in 1991 when the EW antenna was off for special maintenance. Operation of the NS antenna at full power continued during these special maintenance periods.

During the 15- and 75-ampere testing periods in 1987, 1988, and 1989, virtually all transmitter operations were conducted according to a 15-minute rotational schedule commencing on the hour. Each cycle consisted of the following:

- 5 minutes--both antennas off
- 5 minutes--NS antenna only on
- 5 minutes--EW antenna only on.

NRTF-Republic operational logs supplied to IITRI list specific times at which such cycles begin and end. The actual operating times were estimated by assuming a 33% duty cycle for each antenna during the testing period. The rotational schedule was not used after 150-ampere testing began in May 1989.

Figures 32 and 33 show the hours of operation for each antenna or antenna element on a month-by-month basis. The hours of operation for 1986-1988 are shown in Figure 32. During 1986-1988, the NS and EW antennas were never operated simultaneously. Furthermore, in 1986 the NEW and SEW elements which comprise the EW antenna were always operated individually. In 1987 and all future years, these elements were connected in parallel and referred to as the EW antenna. The hours of operation for 1989-1991 are shown in Figure 33. They are broken down into periods of operation with both antennas, the NS antenna only, and EW antenna only.

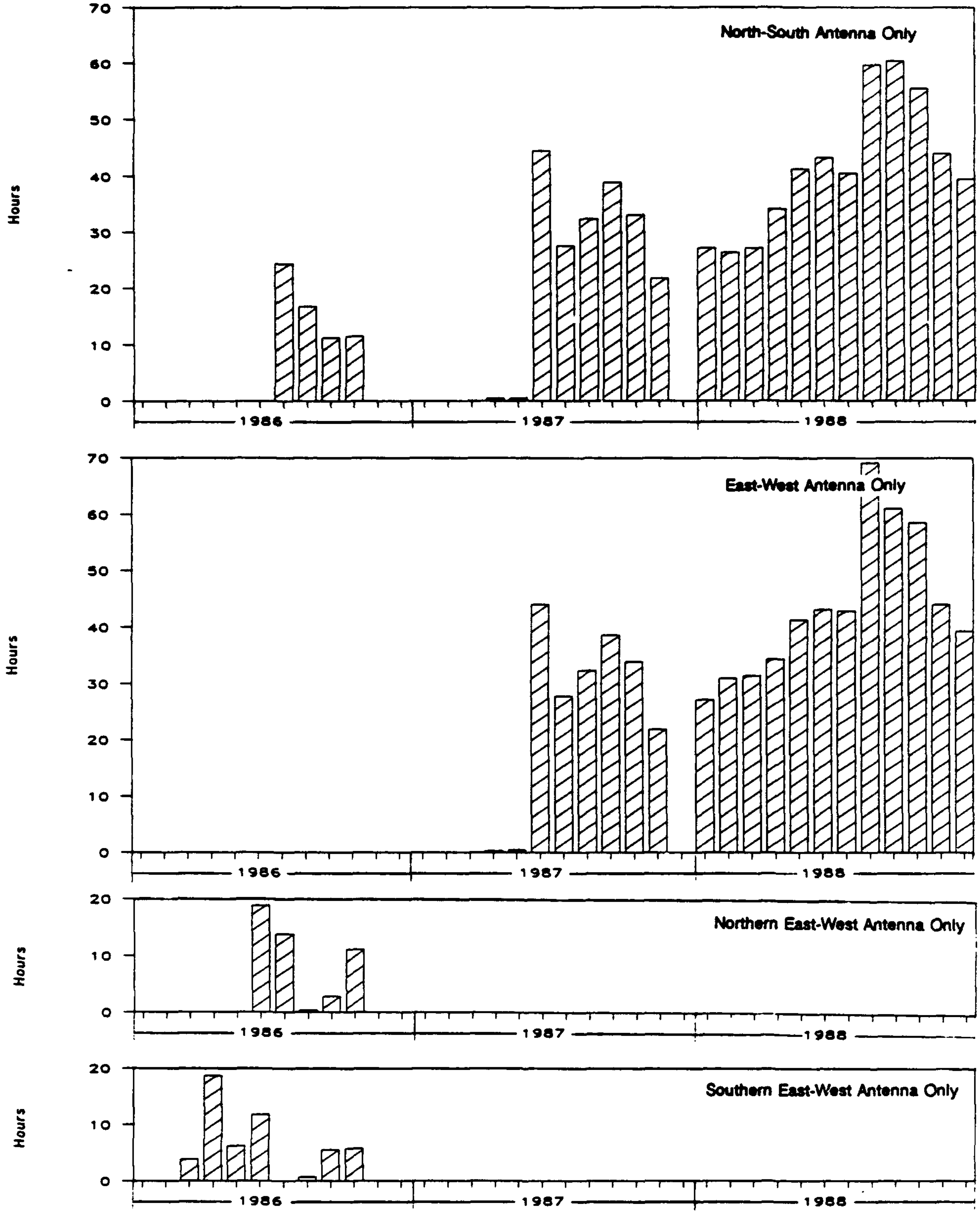


FIGURE 32. NRTF-REPUBLIC MONTHLY OPERATING SUMMARY, 1986-1988.

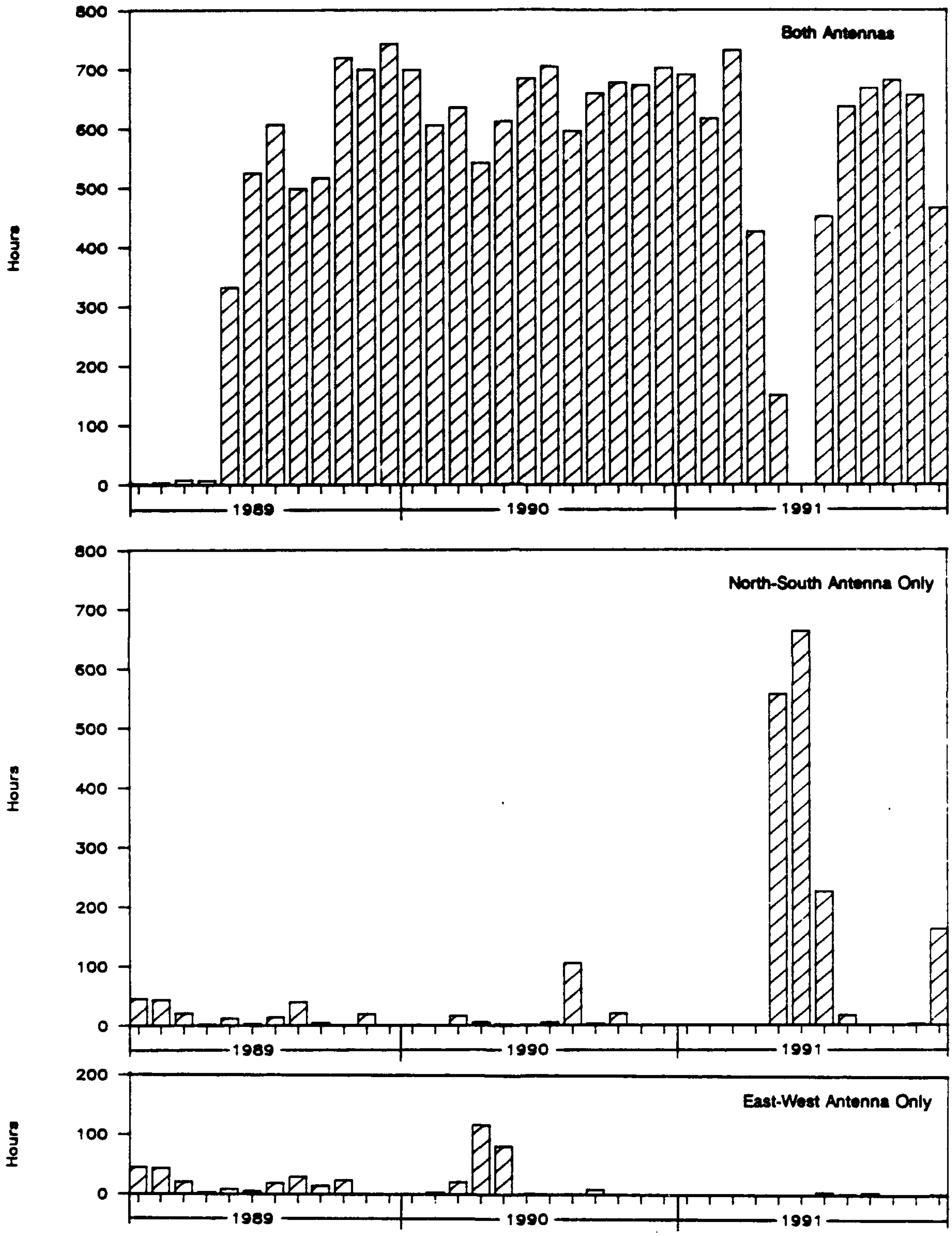


FIGURE 33. NRTF-REPUBLIC MONTHLY OPERATING SUMMARY, 1989-1991.

The pie charts in Figure 34 present NRTF-Republic annual operating summaries for 1986-1991. For each year a pie wedge representing the total percent time of all transmissions is exploded in a second pie, which details this operating time by antenna or antenna element. This figure clearly illustrates the graduation of annual operation times from 1.5% in 1986 to near 90% in 1990 and 1991. The exploded pie wedges provide a "snapshot" history of major operating configuration changes from solo operation of the NS antenna and EW antenna elements in 1986 to nearly exclusive simultaneous operation of both antennas in 1989, 1990, and 1991.

NRTF-Republic operations in 1986-1991 can be summarized as follows:

1986

- The NRTF-Republic was transmitting about 1.5% of the time (about 160 hours) (see Figures 32 and 34).
- About 98% of "on" time was with an unmodulated 76 Hz signal.
- The NS antenna and the NEW and SEW antenna elements were always operated individually.
- Primary operating currents were 4 and 6 amperes for the NS antenna and the NEW antenna element, respectively, and both 6 and 10 amperes for the SEW antenna element.

1987

- The NRTF-Republic was transmitting about 4.5% of the time (about 400 hours) (see Figures 32 and 34).
- 100% of "on" time was with an unmodulated 76 Hz signal.
- The NS and EW antennas were always operated individually.
- 99.6% of the operating time was with a 15-ampere current.

1988

- The NRTF-Republic was transmitting about 11.6% of the time (about 1000 hours) (see Figures 32 and 34).
- About 98% of "on" time was with an unmodulated 76 Hz or 44 Hz signal.
- The NS and EW antennas were always operated individually.
- Primary operating currents were 15 and 75 amperes. 40.6% of "on" time was at 15 amperes, and 59.2% of "on" time was at 75 amperes.

1989

- The NRTF-Republic was transmitting about 58% of the time (about 5100 hours) (see Figures 33 and 34).
- About 57% of "on" time was with a modulated 76 Hz signal, and 28% of "on" time was with an unmodulated 76 Hz signal.
- The NS and EW antennas were operated simultaneously for 91.8% of the "on" time.
- Primary operating currents were 75 and 150 amperes. 95% of "on" time was at 150 amperes.

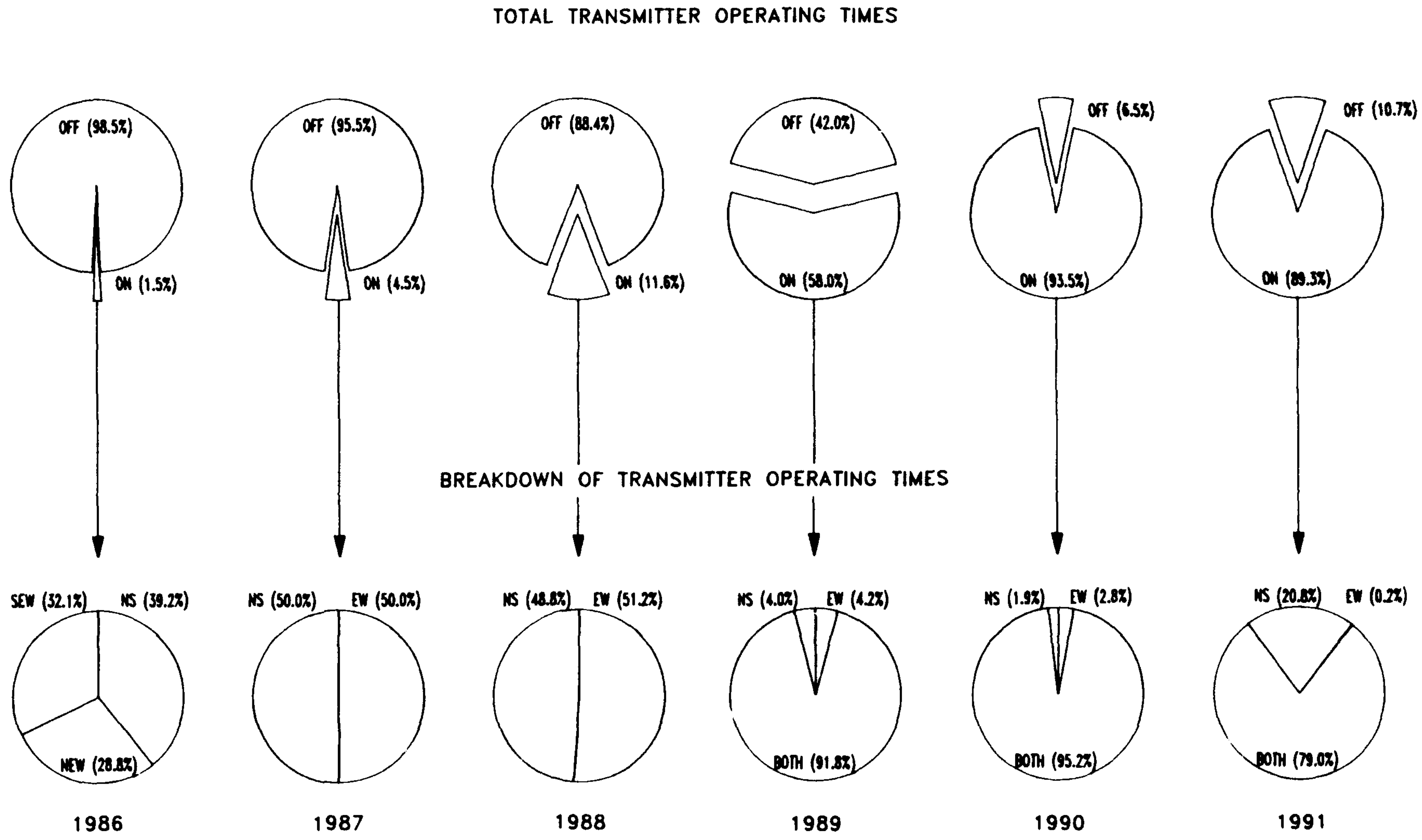


FIGURE 34. NRTF-REPUBLIC OPERATING SUMMARY: PERCENTAGE OF TIME PER ANTENNA ELEMENT, 1986-1991.

1990

- The NRTF-Republic was transmitting about 93.5% of the time (about 8200 hours) (see Figures 33 and 34).
- About 95% of "on" time was with a modulated 76 Hz signal and both antennas operating simultaneously.
- The NS and EW antennas were operated simultaneously for 95.2% of the "on" time.
- All operations were at 150 amperes.

1991

- The NRTF-Republic was transmitting about 89% of the time (about 7825 hours) (see Figures 33 and 34).
- About 79% of "on" time was with a modulated 76 Hz signal and both antennas operating simultaneously.
- About 21% of "on" time was with a modulated 76 Hz signal and only the NS antenna operating.
- Essentially all operations were at 150 amperes with a modulated 76 Hz signal.

5. CONCLUSIONS AND DISCUSSION

Annual EM field measurement surveys in support of the Ecological Monitoring Program were performed during May, June, September, and October of 1991. Measurements were made at a total of 195 points at 50 study sites, compared with 202 points at 50 sites in 1990. New measurement points in 1991 include 10 at the soil arthropods and earthworms study sites and one at an aquatic ecosystems study site. Points were added in order to better characterize spatial EM field variability at study sites in support of added research activity at the sites. The total number of points measured in 1991 decreased because 60 Hz EM fields were not recharacterized at the study laboratory sites this year.

The NRTF-Republic continued operation with a modulated 76 Hz, 150 ampere antenna current during 1991, employing either both antennas or the NS antenna only. 76 Hz EM field measurements were made at most points during simultaneous operation of both antennas. Exceptions to this occurred for some points at earthworms and aquatic ecosystems study sites, where measurements were made during operation of the NS antenna only. At the upland flora treatment study sites, measurement sets were taken during both antenna operating conditions. Measurements of the ambient 60 Hz EM fields at treatment study sites were made only if both antennas were off, since 60 Hz EM fields cannot be measured there during NRTF-Republic modulated signal transmission. At the control study sites, 60 Hz measurements were made regardless of antenna condition.

Incubation bags used to isolate earthworms for reproduction studies were designed and used in the field in 1991. The bags were effective in containing the earthworms while maintaining an electric field intensity level nominally 50% of that in the surrounding soil. Multiple bags were deployed at both the treatment and the control study sites, including reference bags which were monitored by data logger systems. Monitoring of the fields in the bags proved to be very difficult. Field intensities in the control site reference bag were below the logger sensitivity. At the treatment site reference bag, measured field variations show the effects of bag changeouts and subsequent resettling of soil. Measured electric field intensity levels in these bags were somewhat complicated by probe alignment errors during bag change-outs.

Multiple depth monitoring of the earth electric field at the earthworm sites showed some differences in field intensity levels between various soil horizons. Unfortunately, these differences were not consistent between the probe sets. At the treatment study site, surface EM fields appeared somewhat more variable than those of lower depths.

Six data loggers were installed in 1991 to monitor earth electric field temporal variations. Seasonal variations were typically 10% to 30%. Shorter term variations were typically 10% to 20%. At the upland flora study sites, diurnal variations in the electric field were examined. Distinct patterns could be observed at some locations, but variations were less than 5%. Variations resulting from changing antenna operating

conditions could also be observed, particularly at the upland flora study sites where special maintenance on the EW antenna had its greatest impact.

In 1992, the NRTF-Republic is expected to operate both antennas simultaneously with a 150 ampere MSK signal, as it did during 1991. IITRI plans to remeasure all points characterized in 1991. Measurement protocols to be used in 1992 will be determined by the actual antenna status at the time, although they are not expected to differ from those used in 1991.

6. REFERENCES

1. Enk, J. O.; Gauger, J. R. ELF Communications System Ecological Monitoring Program: Measurement of ELF Electromagnetic Fields for Site Selection and Characterization--1983. IIT Research Institute, Technical Report E06549-10, 19 pp. plus appendixes, 1985.

2. Brosh, R. M.; Gauger, J. R.; Zapotosky, J. E. ELF Communications System Ecological Monitoring Program: Measurement of ELF Electromagnetic Fields for Site Selection and Characterization--1984. IIT Research Institute, Technical Report E06549-14, 37 pp. plus appendixes, 1985.

3. Brosh, R. M.; Gauger, J. R.; Zapotosky, J. E. ELF Communications System Ecological Monitoring Program: Electromagnetic Field Measurements and Engineering Support--1985. IIT Research Institute, Technical Report E06549-24, 48 pp. plus appendixes, 1986.

4. Haradem, D. P.; Gauger, J. R.; Zapotosky, J. E. ELF Communications System Ecological Monitoring Program: Electromagnetic Field Measurements and Engineering Support--1986. IIT Research Institute, Technical Report E06549-37, 52 pp. plus appendixes, 1987.

5. Haradem, D. P.; Gauger, J. R.; Zapotosky, J. E. ELF Communications System Ecological Monitoring Program: Electromagnetic Field Measurements and Engineering Support--1987. IIT Research Institute, Technical Report E06595-1, 54 pp. plus appendixes, 1988.

6. Haradem, D. P.; Gauger, J. R.; Zapotosky, J. E. ELF Communications System Ecological Monitoring Program: Electromagnetic Field Measurements and Engineering Support--1988. IIT Research Institute, Technical Report E06595-5, 69 pp. plus appendixes, 1989.

7. Haradem, D. P.; Gauger, J. R.; Zapotosky, J. E. ELF Communications System Ecological Monitoring Program: Electromagnetic Field Measurements and Engineering Support--1989. IIT Research Institute, Technical Report E06620-5, 77 pp. plus appendixes, 1990.

8. ELF Communications System Ecological Monitoring Program: Wetland Studies--Final Report. IIT Research Institute, Technical Report E06620-2, November 1989, 250 pp.

9. ELF Communications System Ecological Monitoring Program: Slime Mold Studies--Final Report. IIT Research Institute, Technical Report E06620-3, January 1990, 83 pp.

10. ELF Communications System Ecological Monitoring Program: Wisconsin Bird Studies--Final Report. IIT Research Institute, Technical Report E06628-2, February 1991, 99 pp.

11. Haradem, D. P.; Gauger, J. R.; Zapotosky, J. E. ELF Communications System Ecological Monitoring Program: Electromagnetic Field Measurements and Engineering Support--1990. IIT Research Institute, Technical Report E06628-3, 87 pp. plus appendixes, 1991.

APPENDIX A

SMALL MAMMALS AND NESTING BIRDS STUDIES

SMALL MAMMALS AND NESTING BIRDS STUDIES

These studies monitor parental care, nestling growth and maturation, fecundity, homing, activity patterns, embryological development, and metabolic physiology of small mammals and nesting birds. The electric and magnetic fields in the air are considered important factors to be examined in orientation and other behavior patterns of birds. The electric and magnetic fields in the earth and near its surface are important to the small mammals studies. The air electric field and magnetic field in the laboratory where study animals undergo physiological testing, and in the holding areas used prior to these tests, are also of importance.

IITRI field crews made ELF electromagnetic (EM) field measurements at 63 measurement points within the five treatment sites, four control sites, three (bird) displacement sites, and the remote holding facility for the small mammals and nesting birds studies in 1991. The measurement regime differed from 1990 in that measurements were not taken at the Crystal Falls laboratory to assess the 60 Hz EM exposures. Documentation of previous measurements and EM field shielding activities at the laboratory is included in this appendix, however, for easy reference. Measurement dates for 1991 and previous years appear in Table A-1.

TABLE A-1. EM FIELD MEASUREMENT DATES
Small Mammals and Nesting Birds Studies

Year	Measurement Dates		
1983	May 23, 24, 26	Jun 9, 14, 15	Jul 13, 14
1984	May 16, 17	Aug 6, 7, 9, 10, 14-16, 21, 22	
1985	Jul 15, 17, 18, 22-24		
1986	Oct 2, 3, 6, 8, 14-17		
1987	Sep 24, 28-30	Oct 1, 5, 6, 8	Dec 11
1988	Sep 19-22, 27, 28	Oct 3-5	Nov 11
1989	Feb 21	Sep 13-15, 18, 20-22	Oct 12
1990	Jan 9, 10, 22	Sep 24, 25, 27	Oct 2, 4, 8-10
1991	Sep 23, 24, 26, 27	Oct 1-4, 16	

The positions of all sites relative to the NRTF-Republic are shown on the composite map in Figure A-1. The site numbers listed on the map are those used by IITRI. Table A-2 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites. Details of measurement locations within sites are shown in Figures A-2 through A-16.

TABLE A-2. SITE NUMBER CROSS-REFERENCE
Small Mammals and Nesting Birds Studies

IITRI Site No.	Investigator's Site Name	Location Township	Range	Section(s)
1T1	Pirlot Road	T43N	R29W	23, 26
1T2	Cleveland Homestead	T44N	R29W	25
1T4	North Turner Road	T43N	R29W	1
1T5	Ford River North	T43N	R29W	14
1T6	Ford River South	T43N	R29W	14
1C1	Michigamme North	T44N	R31W	13
1C3	Michigamme South	T44N	R31W	24
1C4	Panola Plains	T42N	R32W	10
1C6	Tachycineta Meadow	T42N	R31W	3
1D1	Cleveland Homestead Displacement	T47N	R28W	36
1D2	North Turner Road Displacement	T46N	R28W	12
1D3	Panola Plains Displacement	T45N	R31W	14
1L1	Crystal Falls Laboratory	T43N	R32W	29
1L4	Remote Holding Facility	T42N	R32W	9

EM field measurements for 1991 and previous years are found in Tables A-3 through A-8. Tables A-3, A-4, and A-5 present 60 Hz data for the air electric field, earth electric field, and magnetic flux density, respectively. These tables include data for 18 measurement locations that are no longer active. This has been done in order to provide historical measurement values at study sites where new measurement locations were laid out after antenna construction in 1986. Tables A-6, A-7, and A-8 present 76 Hz data for these three fields as well as the corresponding operating currents of the NRTF-Republic for each year. 60 Hz data for the air electric field and magnetic flux density measured at the Crystal Falls laboratory from 1986 to 1990 appear in Tables A-9 and A-10.

Plots of the 60 Hz EM field profiles for the five nest box sites for the years 1987 through 1991 are presented in Figures A-17 through A-23. Considerable year-to-year variability in these fields is evident. The primary factors in this variability are changes in power line loading conditions (which are unknown) and differences in the configuration of the antennas at the time of measurement. Notes on the antenna configurations are included in the tables primarily for engineering use. The 60 Hz measurements in 1986-1991

(excluding 1989) were typically taken while the antennas were off, and are representative of 60 Hz levels present during maintenance periods. In 1989, measurements were taken at the treatment sites during full-power operation of the antennas with an unmodulated signal. These values indicate that 60 Hz EM fields present during operation of the antennas are comparable to those present when the antennas are off. It should be noted that a significant gradient in the 60 Hz fields exists across the nest box treatment sites because of their size and the 60 Hz coupling to the nearby NS antenna.

Annual variations in the 60 Hz fields measured at the control study sites are also caused by differences in power line loading, but are not dependent on the antennas or their configuration because of the distance of these sites from the antennas. The 60 Hz field values at the control sites show lower spatial variation compared to those at the treatment sites because the antenna is not present to establish a field gradient.

Overall, the 60 Hz EM fields measured at all of the study sites in 1991 are consistent with previous field values and with the expected differences in power line loads and antenna configuration. Regardless of the field variability associated with the measurement condition, 76 Hz EM fields at treatment sites consistently dominate the 60 Hz EM fields at treatment and control sites, and the ratios of 60 Hz EM fields between matched treatment/control sites continue to meet exposure criteria guidelines established at the beginning of the study.

The 76 Hz EM field measurements in 1991 were made with 150 ampere antenna currents, the predominant operating current of the NRTF-Republic since 4 May 1989. The antenna currents at which measurements were made in each year are shown in the column headings of Tables A-6 through A-8. The annual increases in field magnitudes reflect the level of antenna current at the time of measurement: 4 or 6 amperes in 1986, 15 amperes in 1987, 75 amperes in 1988, and 150 amperes in 1989, 1990, and 1991. The 1991 measurements are consistent with the 1989 and 1990 measurements at the same current, and proportional in the 1986, 1987 and 1988 measurements made at lower currents.

Plots of the 76 Hz EM field profiles for the five nest box test sites for the years 1987 through 1991 are presented in Figures A-24 through A-37. The annual increases in field magnitudes illustrated by these profiles reflect the level of antenna current at the time of measurement: An estimate of the EM field levels for any nest box at a treatment site can be obtained graphically from Figures A-24 through A-37 given the perpendicular distance of the nest box from the antenna wire.

EM field measurements were made at the release points for the Cleveland Homestead, North Turner Road, and Panola Plains tree swallow homing transects. The EM field environment along the flight paths can be estimated using Figures A-38 and A-39, which show the locations of the bird flight paths and the ELF antenna relative to positions of high-voltage 60 Hz transmission lines and 60 Hz power distribution lines, respectively. The EM fields generated by the distribution lines are of magnitudes similar to those that are generated by the ELF antenna when it is operating at full power. The EM fields produced by the

transmission lines can be considerably higher, depending on operating conditions. The air electric field generated by a transmission line may be as much as 100 times greater than that of the ELF antenna; the magnetic flux generated by a transmission line is dependent on the load current, and may be several times greater than that of the ELF antenna.

The 60 Hz field intensities measured at the Crystal Falls laboratory in 1989 were nominally 100 times greater than those at the study sites, and were of the same order of magnitude as the 76 Hz intensities at the treatment sites. IITRI made efforts to reduce the ambient field levels in critical laboratory work areas by recommending methods for shielding sources of electric fields and by providing magnetic shielding for the containers used for metabolic testing.

Magnetic and air electric field shielding in the Crystal Falls laboratory was discussed in a previous report.[11] Table A-9 presents 60 Hz air electric field data before and after shielding was implemented in the Crystal Falls laboratory. It can be seen from this table that the air electric field shielding reduced the fields by factors of 4.5 to 20.

Figure A-40 shows the locations of magnetic shields used to reduce the 60 Hz magnetic field exposures in the cooling bath during metabolic tests. The effectiveness of the shielding is seen in Table A-10, which gives the magnetic flux densities inside the test containers under three different shielding configurations. The final shielding configuration served to reduce the magnetic fields inside the test containers by factors of 30 to 68.

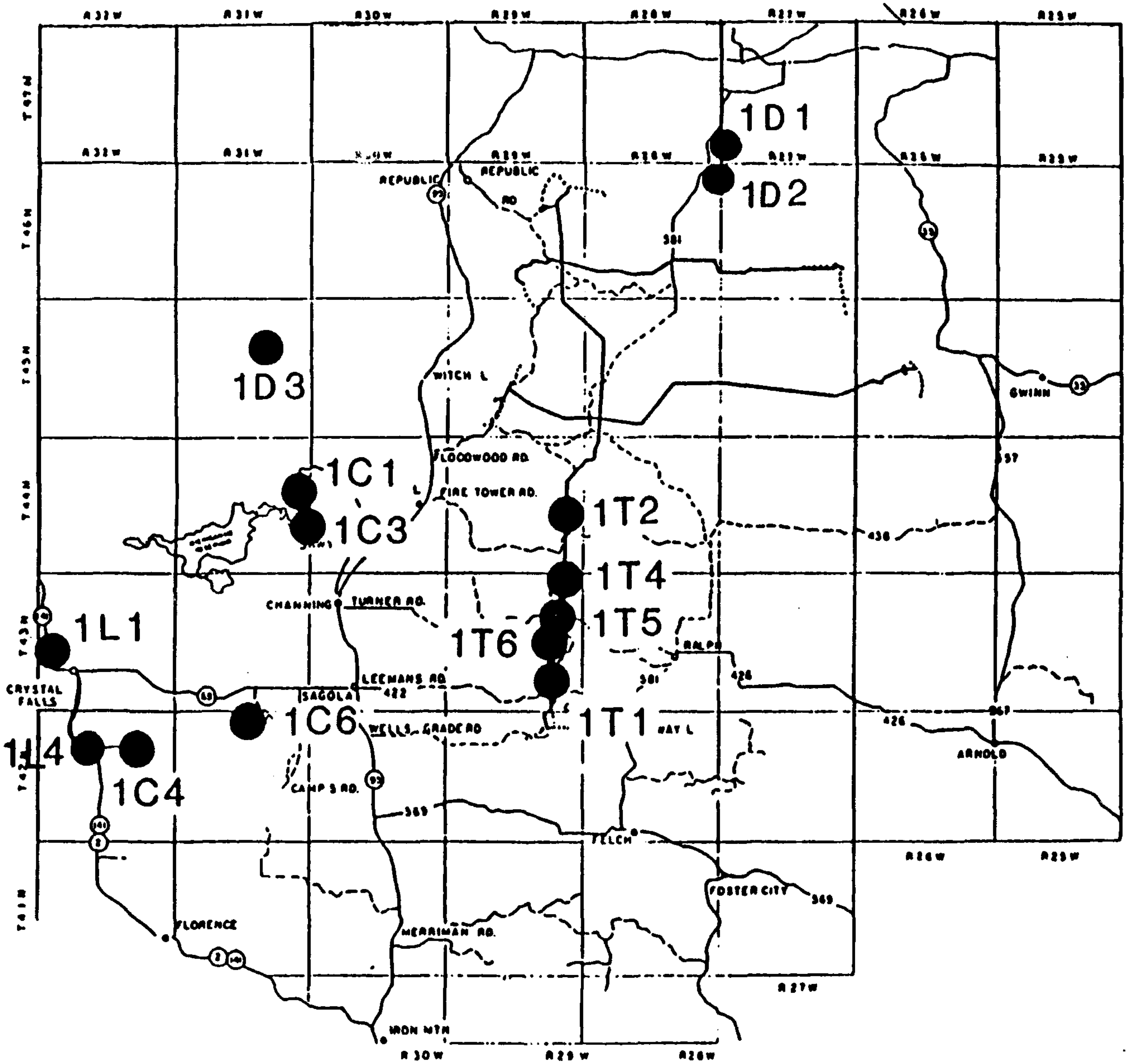


FIGURE A-1. POSITIONS OF SMALL MAMMALS AND NESTING BIRDS STUDY SITES RELATIVE TO NRTF-REPUBLIC ANTENNA ELEMENTS.

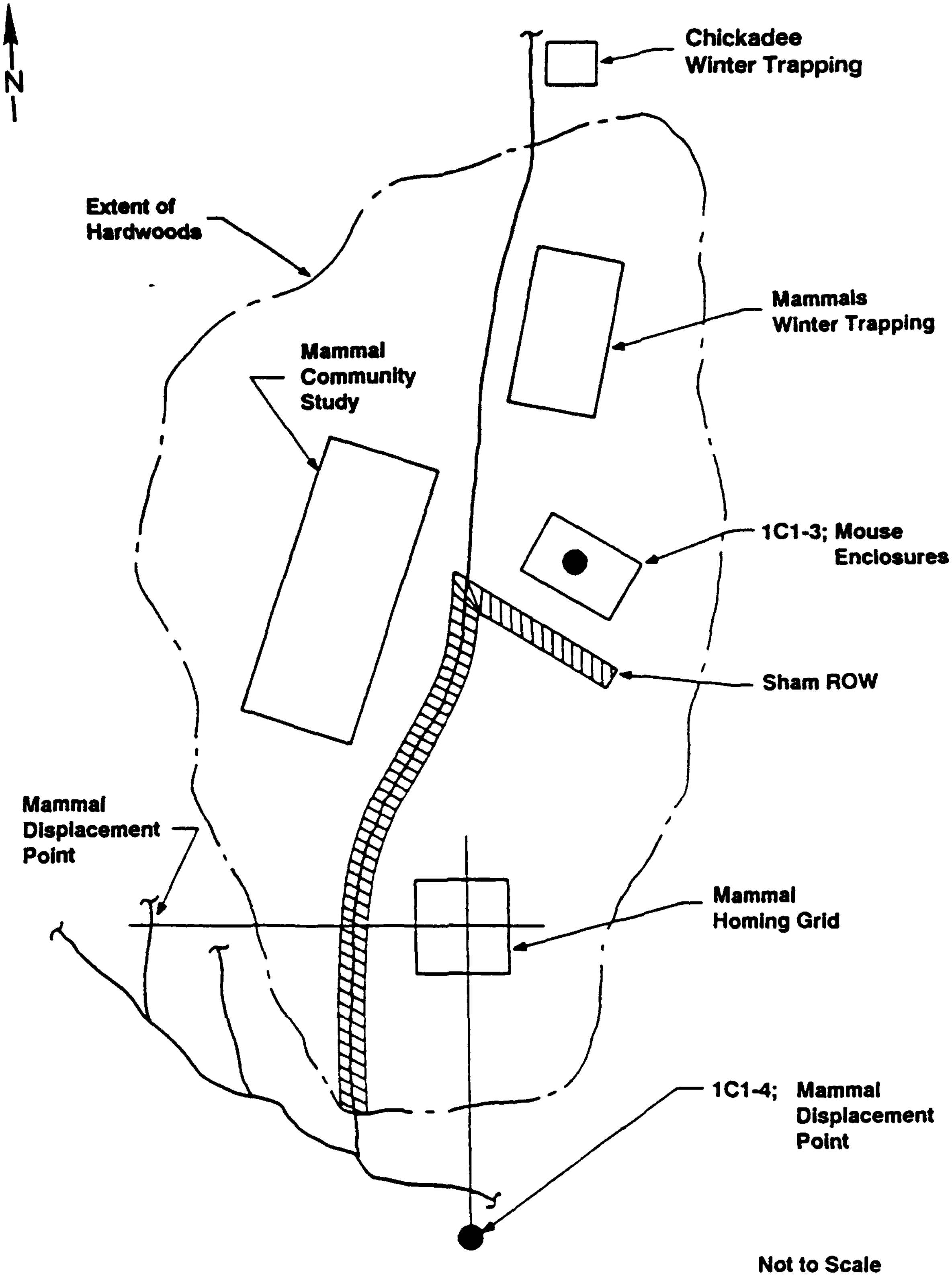


FIGURE A-2. MEASUREMENT POINTS AT MICHIGAMME NORTH; 1C1-3, 4.

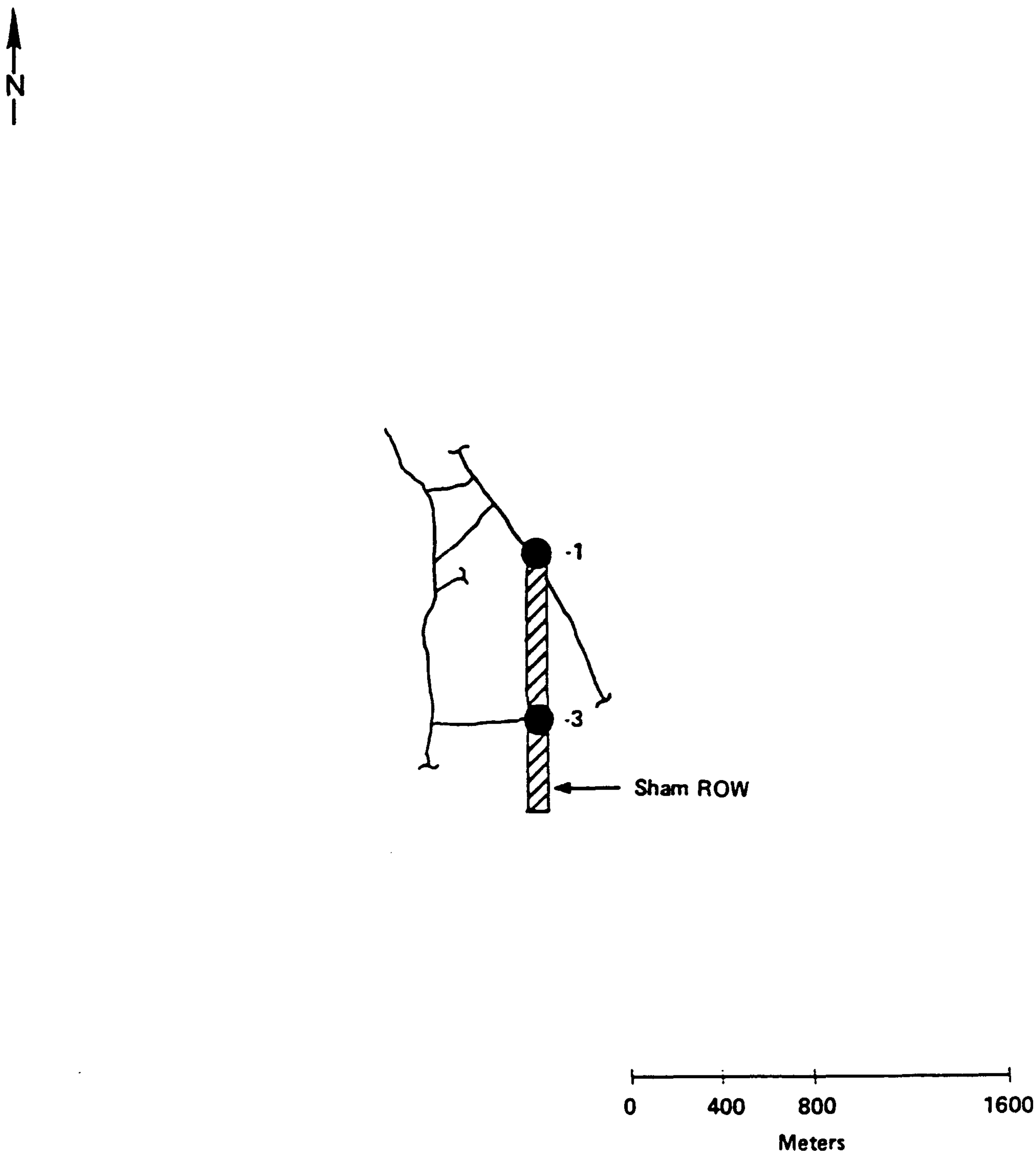


FIGURE A-3. MEASUREMENT POINTS AT MICHIGAMME SOUTH; 1C3-1, 3.

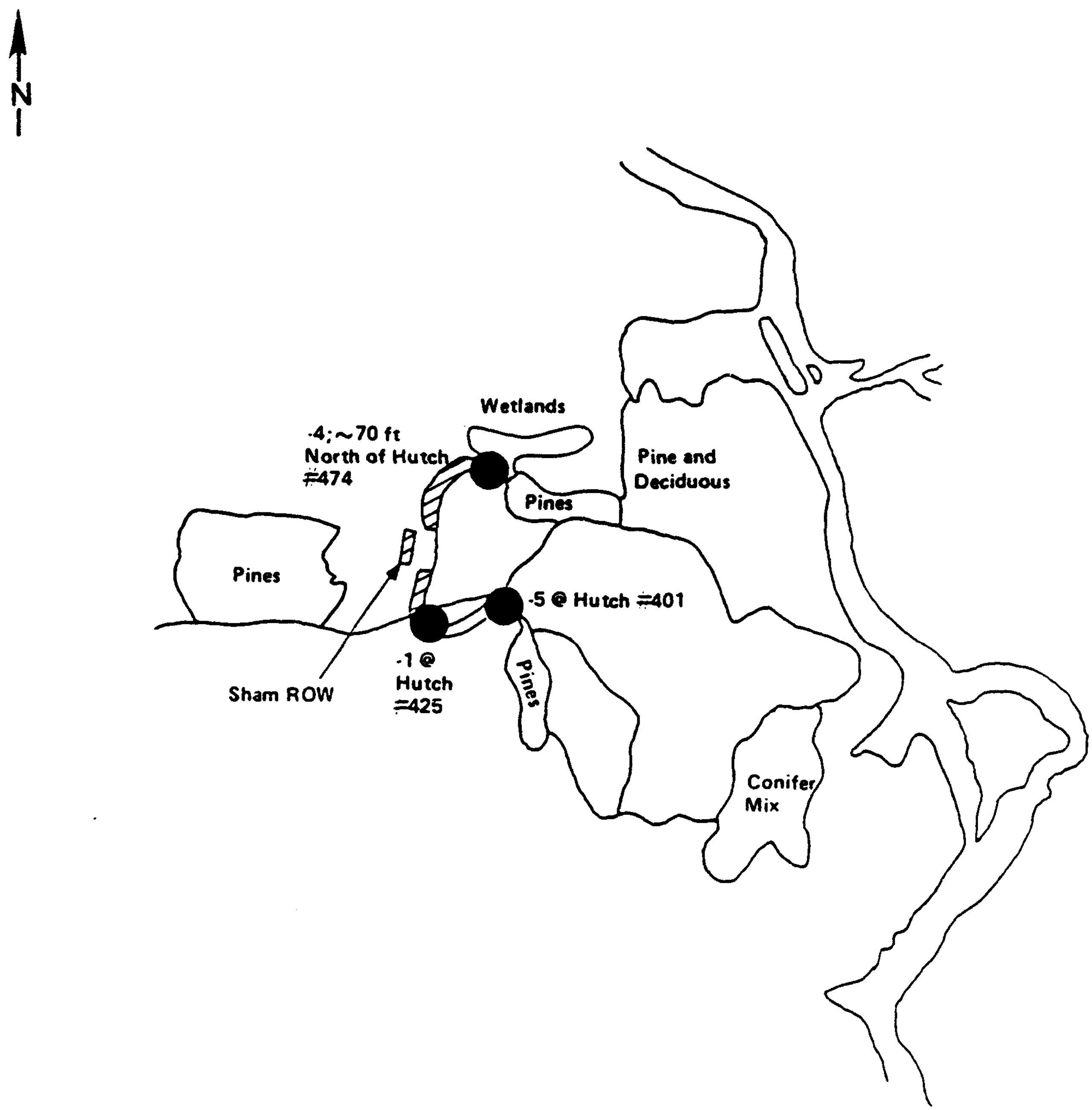


FIGURE A-4. MEASUREMENT POINTS AT PANOLA PLAINS; 1C4-1, 4, 5.

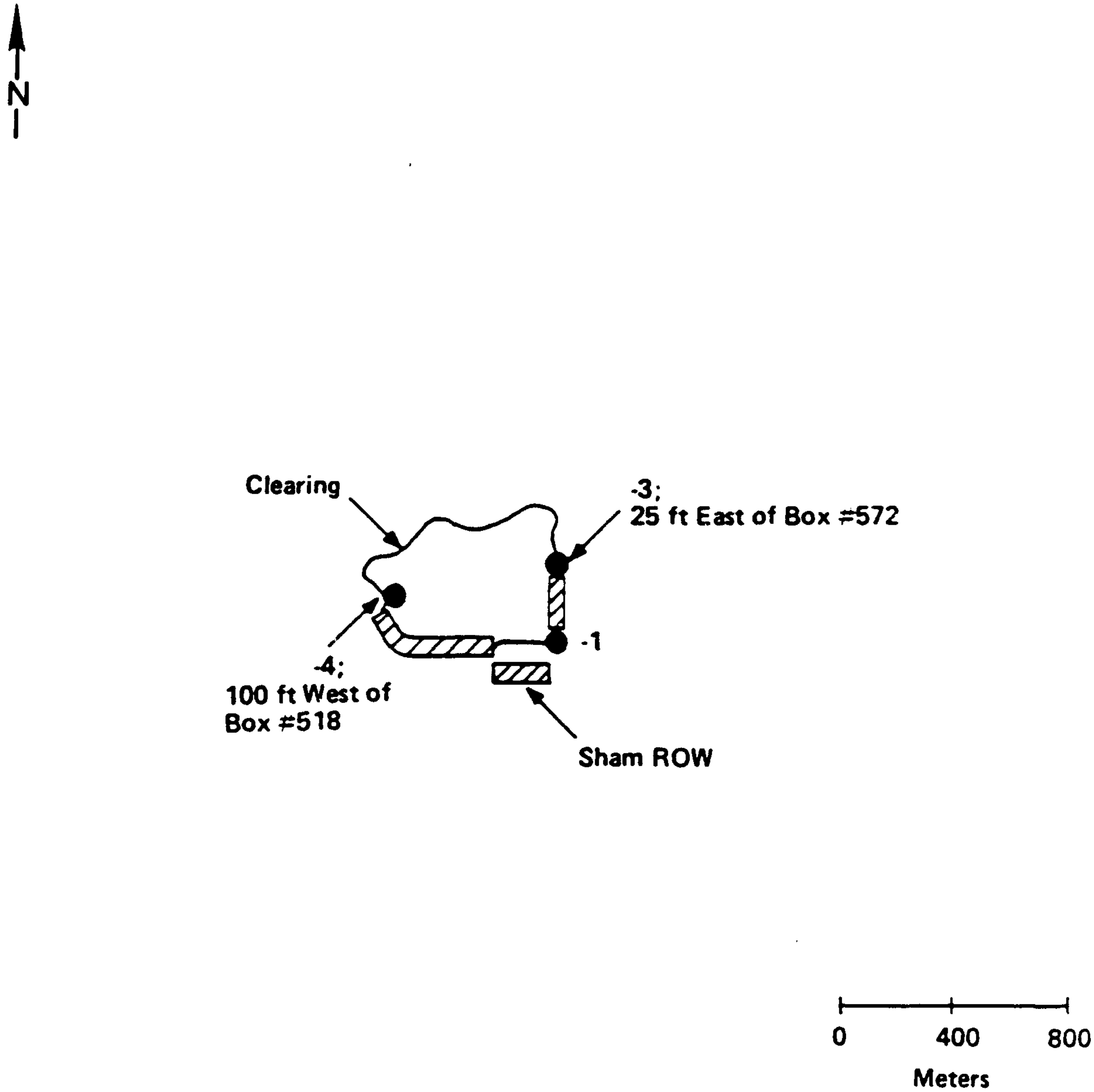


FIGURE A-5. MEASUREMENT POINTS AT TACHYCINETA MEADOW; 1C6-1, 3, 4.

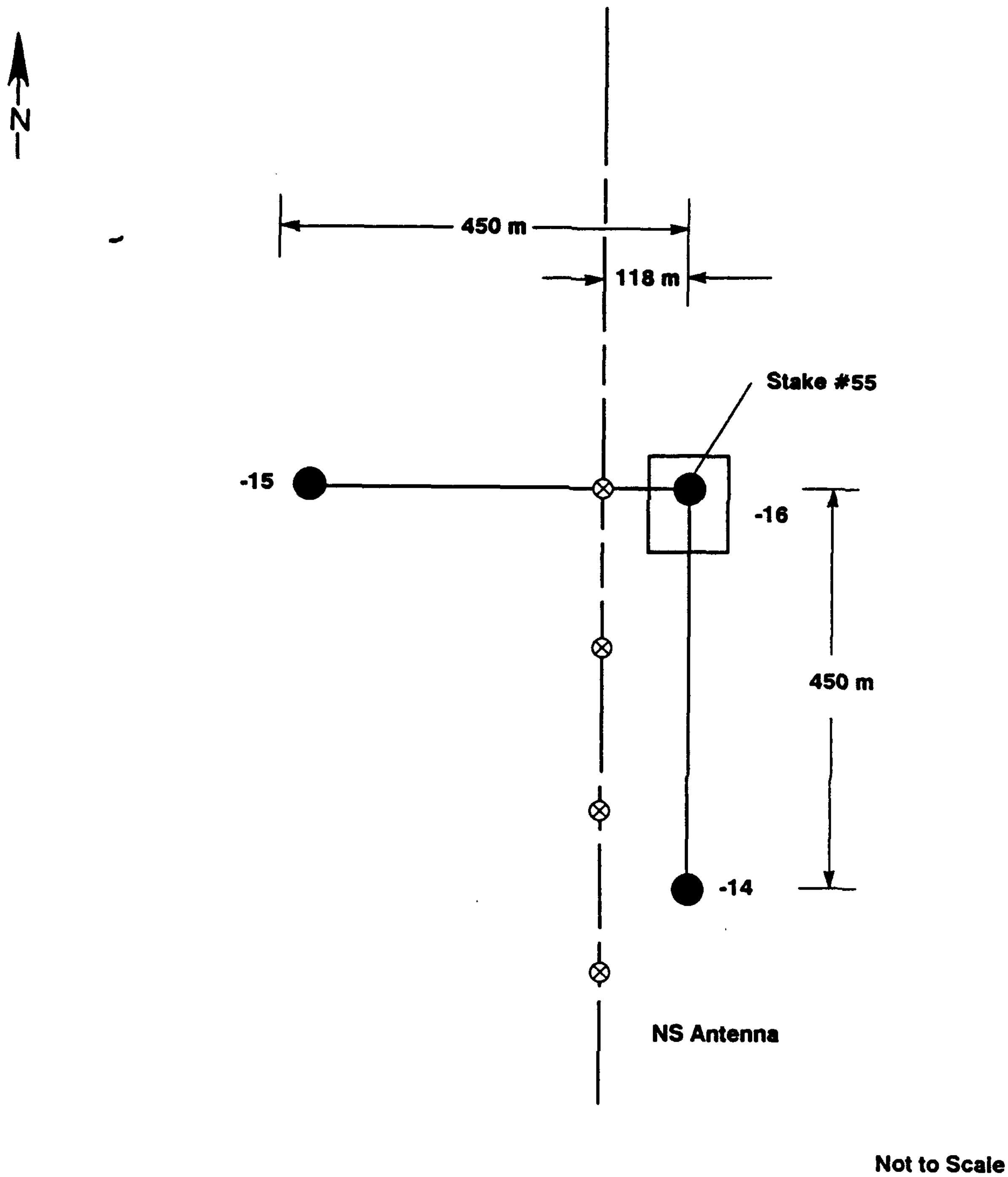


FIGURE A-6. MEASUREMENT POINTS AT PIRLOT ROAD MAMMAL DISPLACEMENT; 1T1-14, 15, 16.

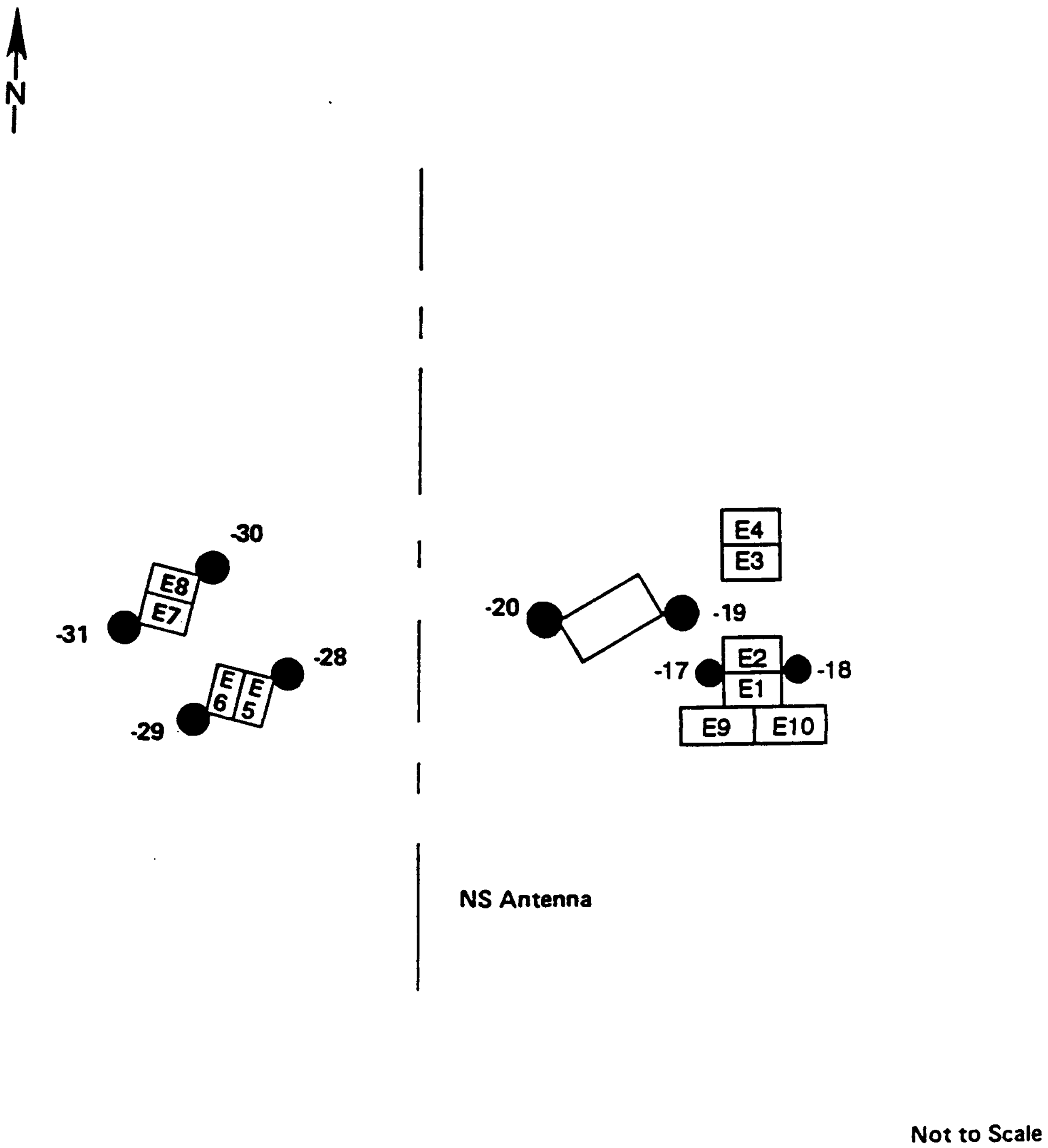


FIGURE A-7. MEASUREMENT POINTS AT PIRLOT ROAD MOUSE ENCLOSURES; 1T1-17 THROUGH 20, 28 THROUGH 31.

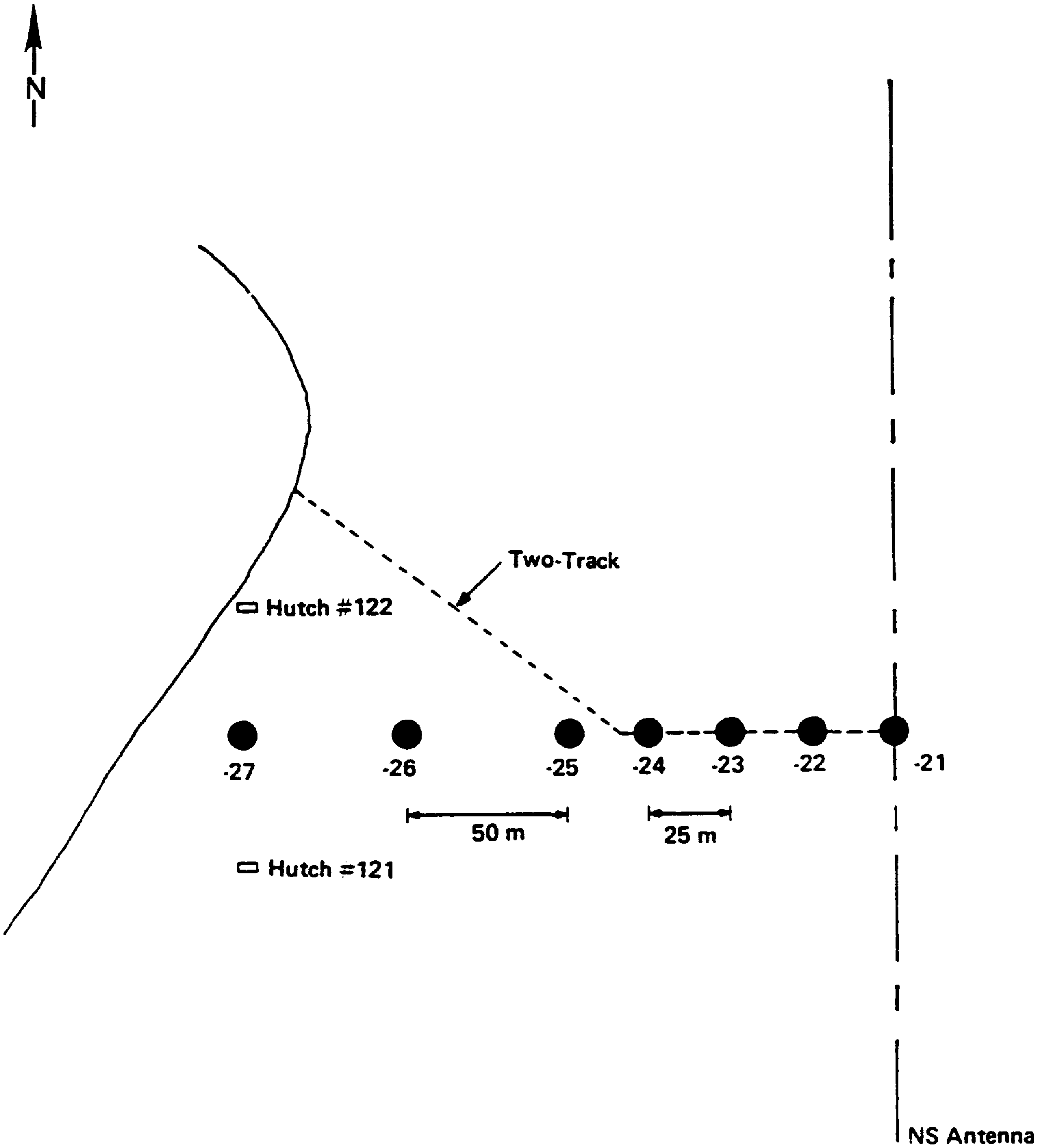


FIGURE A-8. MEASUREMENT POINTS AT PIRLOT ROAD; 1T1-21 THROUGH 27.

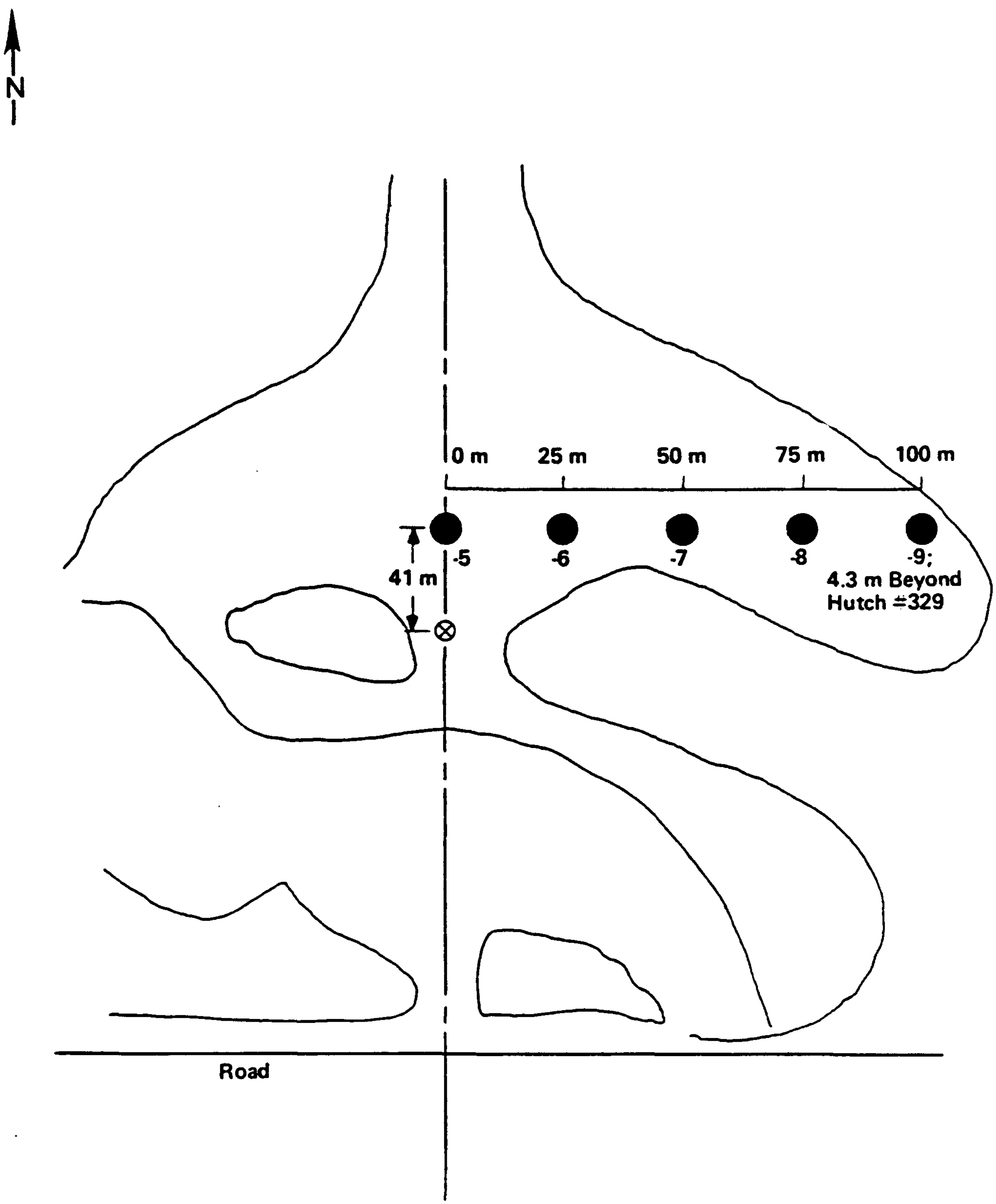


FIGURE A-9. MEASUREMENT POINTS AT CLEVELAND HOMESTEAD; 1T2-5 THROUGH 9.

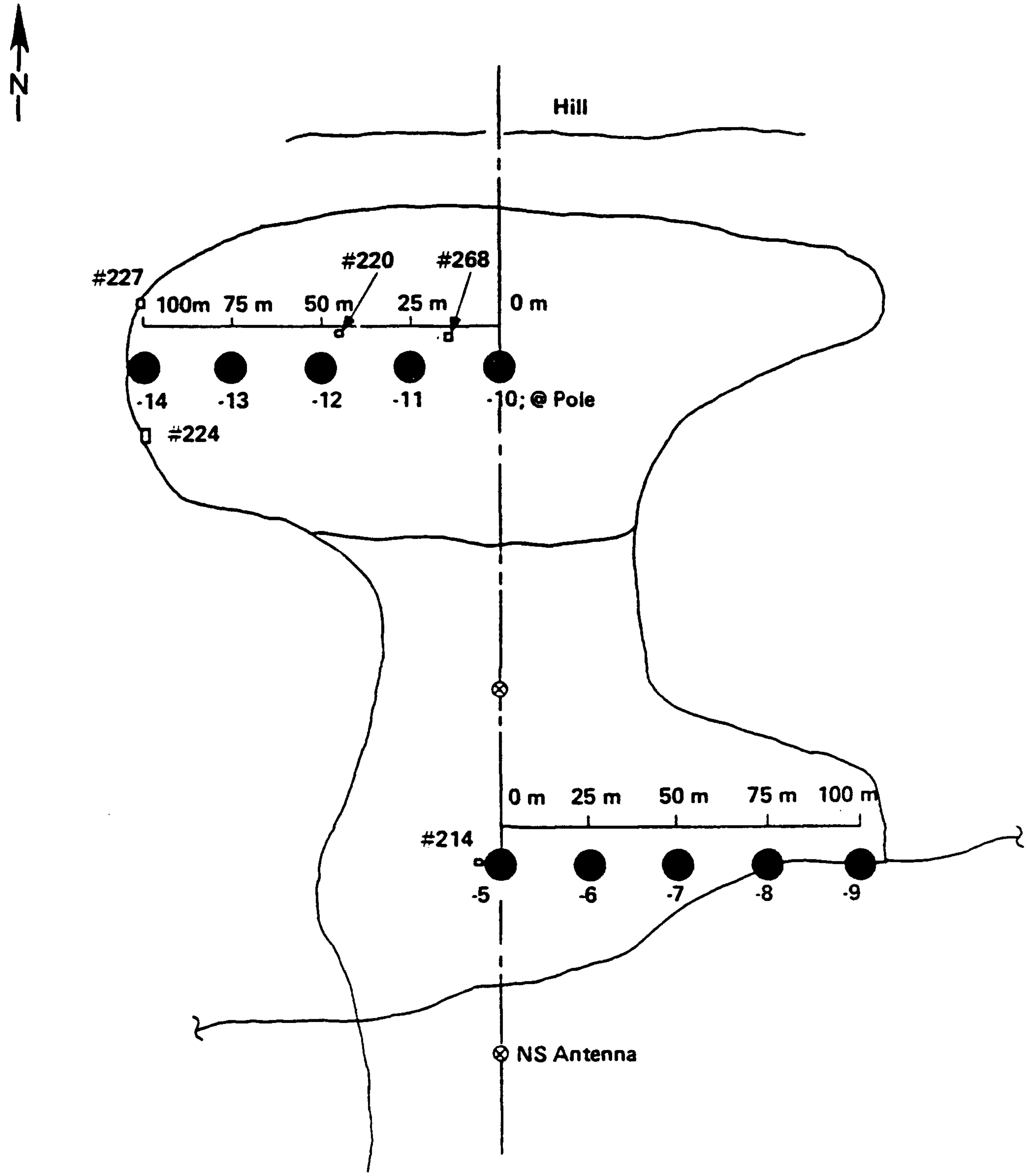


FIGURE A-10. MEASUREMENT POINTS AT NORTH TURNER ROAD; 1T4-5 THROUGH 14.

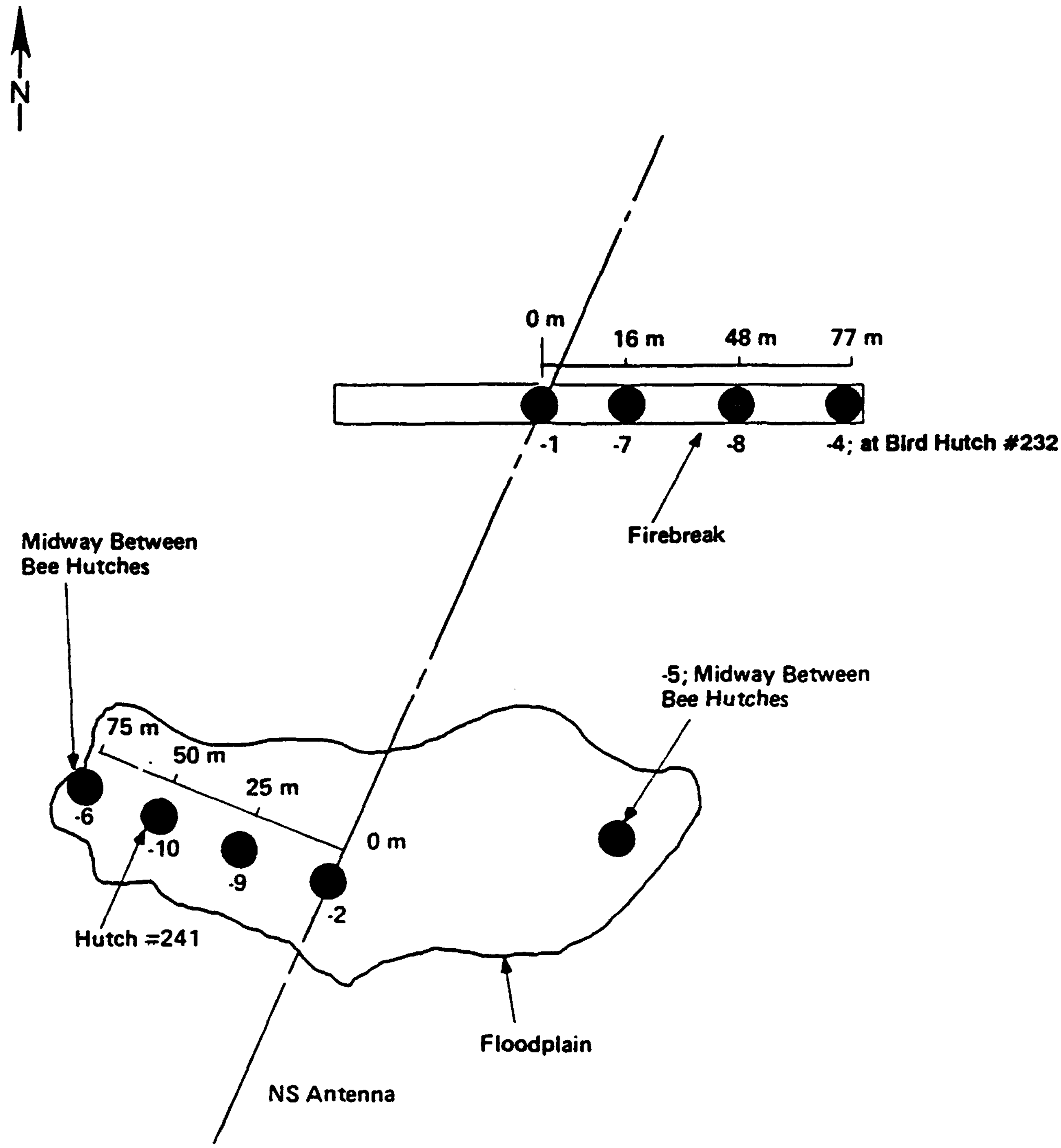


FIGURE A-11. MEASUREMENT POINTS AT FORD RIVER NORTH;
1T5-1, 2, 4, 6, 7, 8, 9, 10.

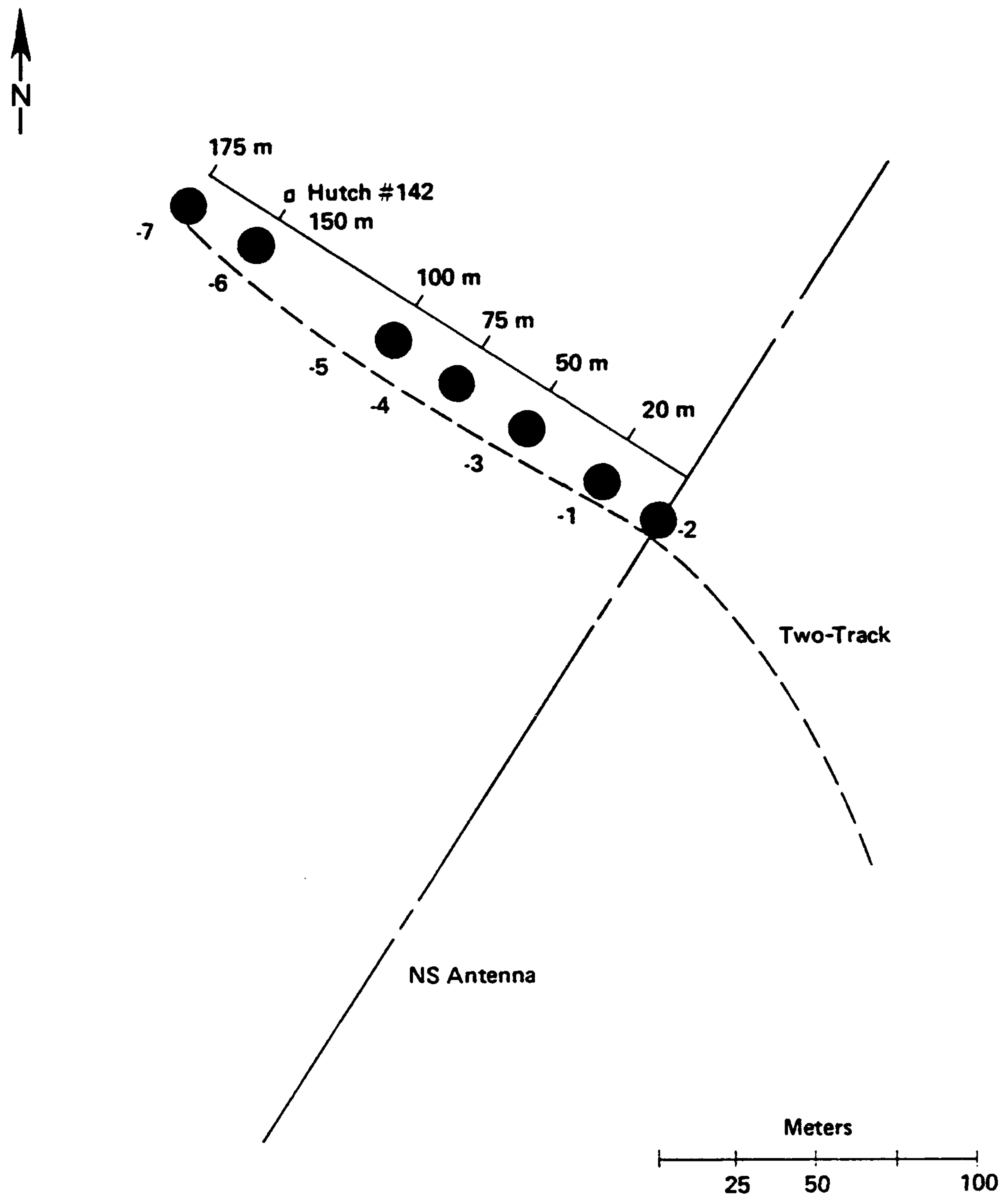


FIGURE A-12. MEASUREMENT POINTS AT FORD RIVER SOUTH; 1T6-1 THROUGH 7.

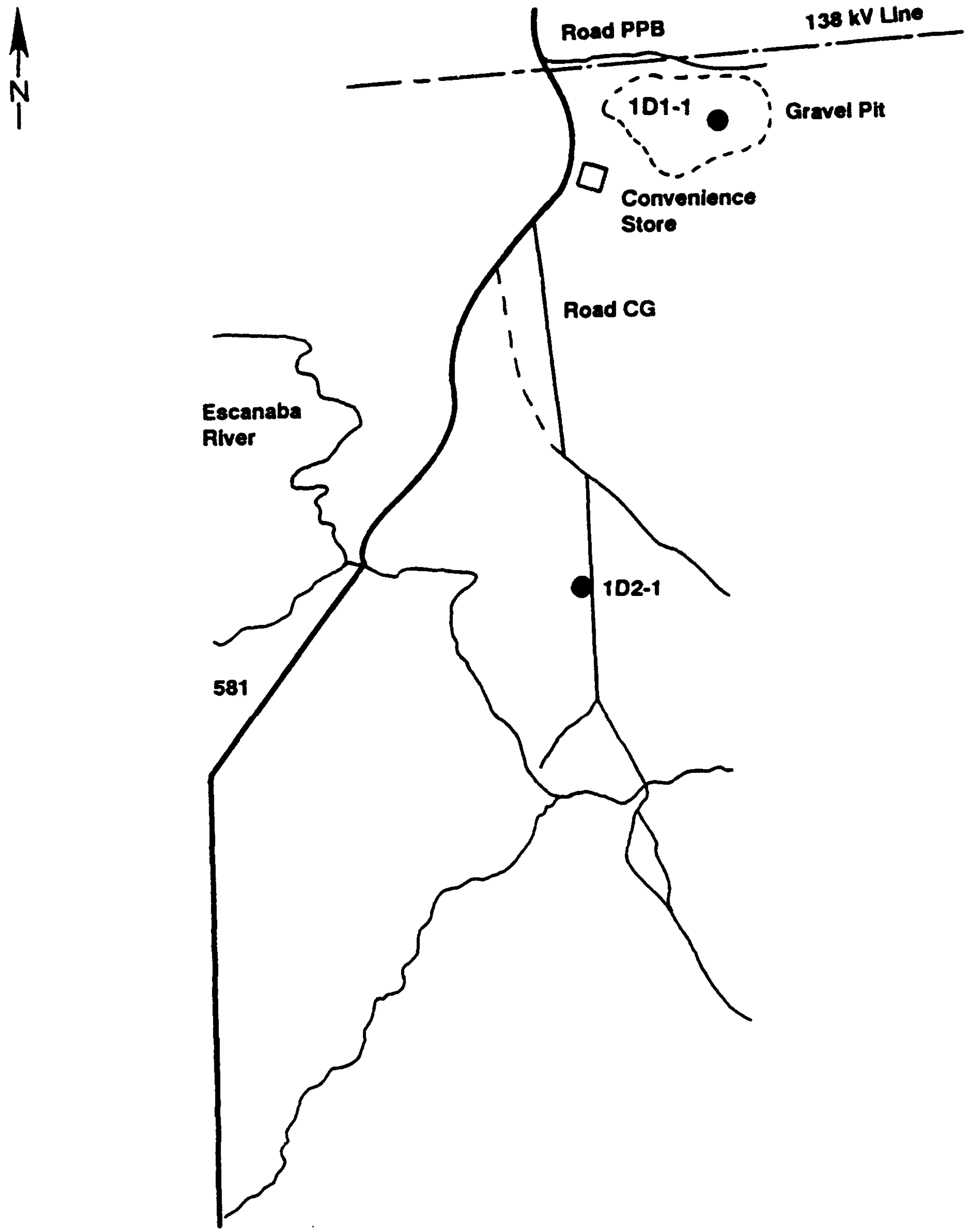


FIGURE A-13. MEASUREMENT POINTS AT CLEVELAND HOMESTEAD AND NORTH TURNER ROAD DISPLACEMENT POINTS; 1D1-1 AND 1D2-1.

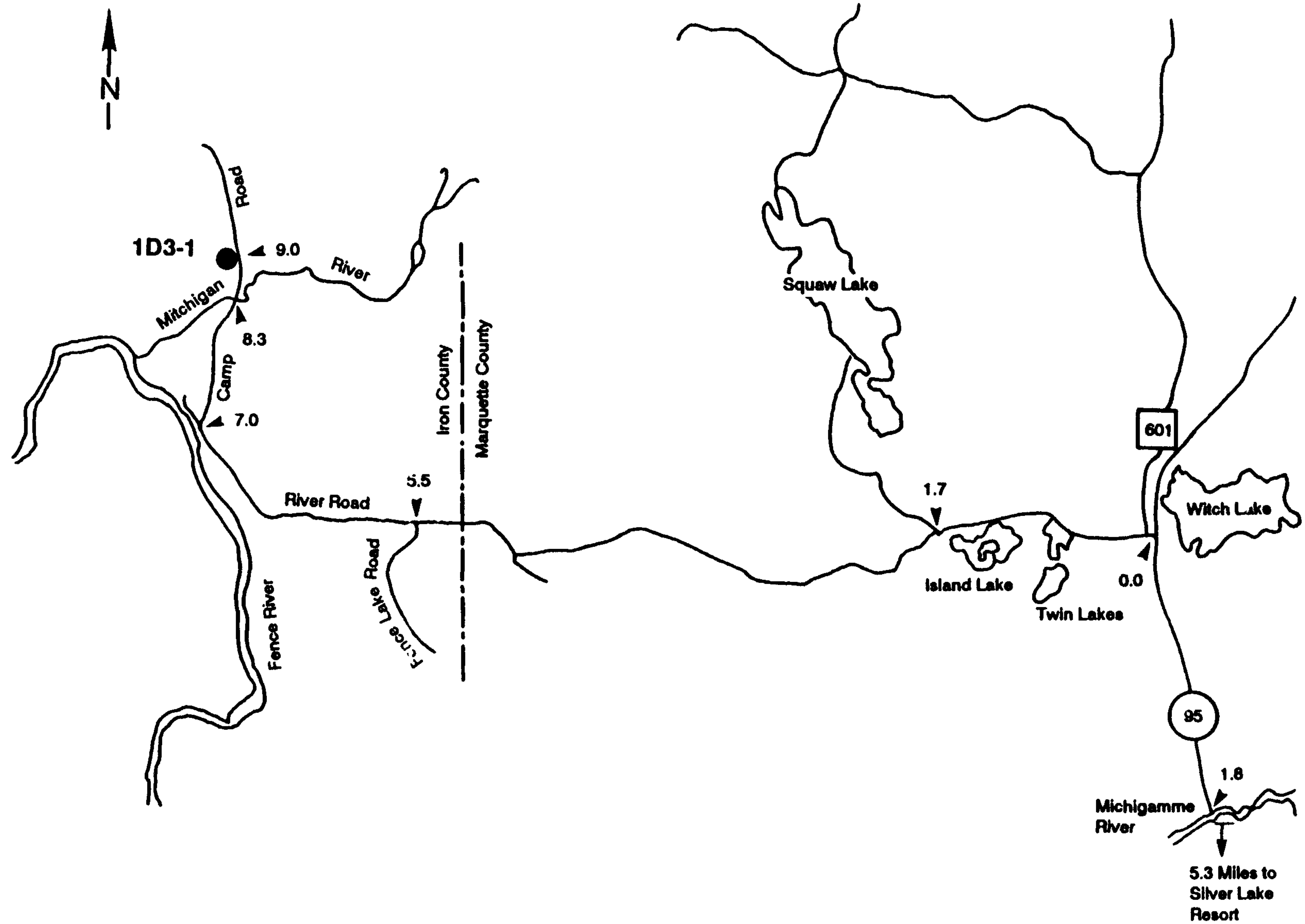


FIGURE A-14. MEASUREMENT POINT AT PANOLA PLAINS DISPLACEMENT; 1D3-1.

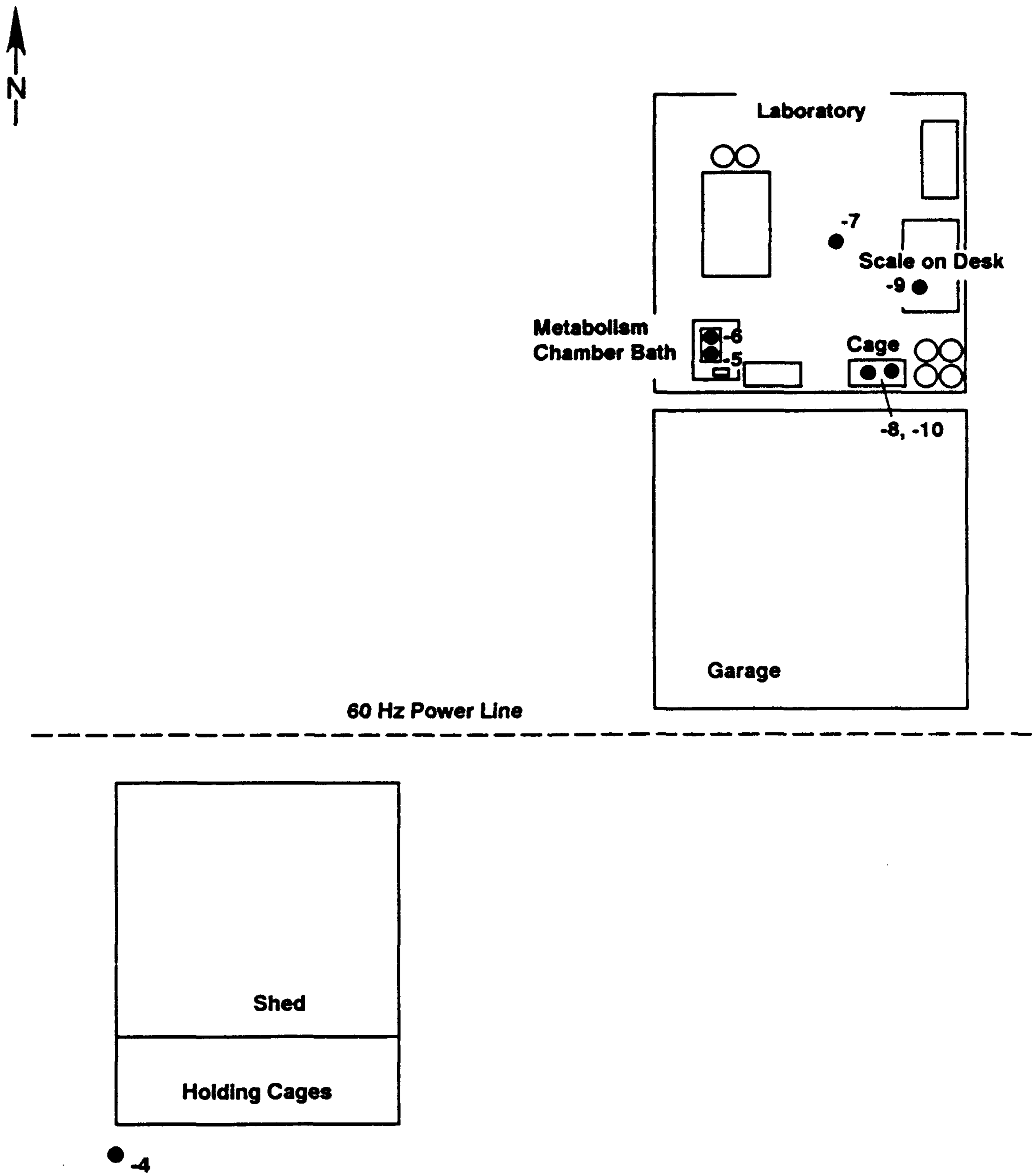


FIGURE A-15. MEASUREMENT POINTS AT MAMMAL LABORATORY; 1L1-4 THROUGH 1L1-10.

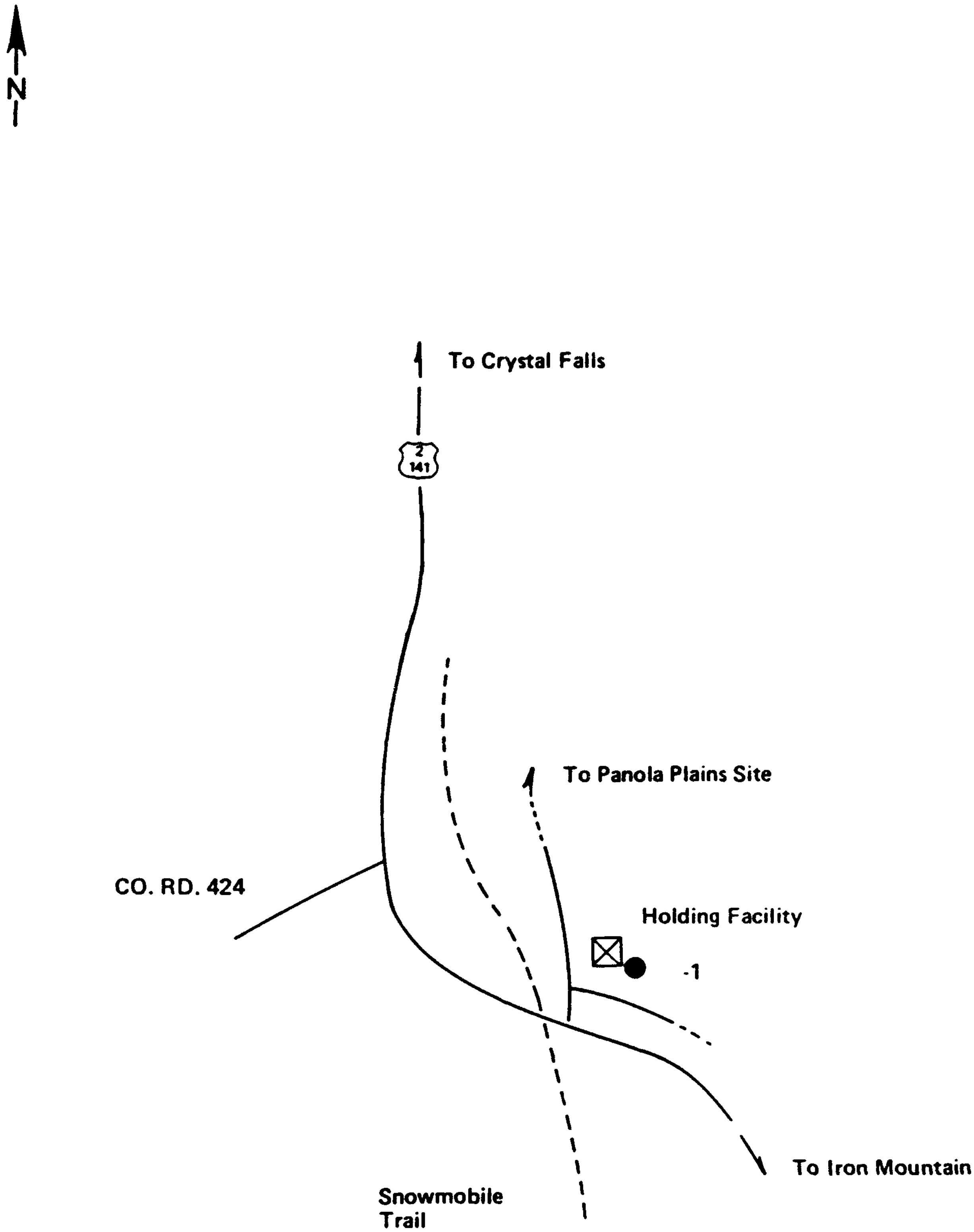


FIGURE A-16. MEASUREMENT POINT AT REMOTE HOLDING FACILITY; 1L4-1.

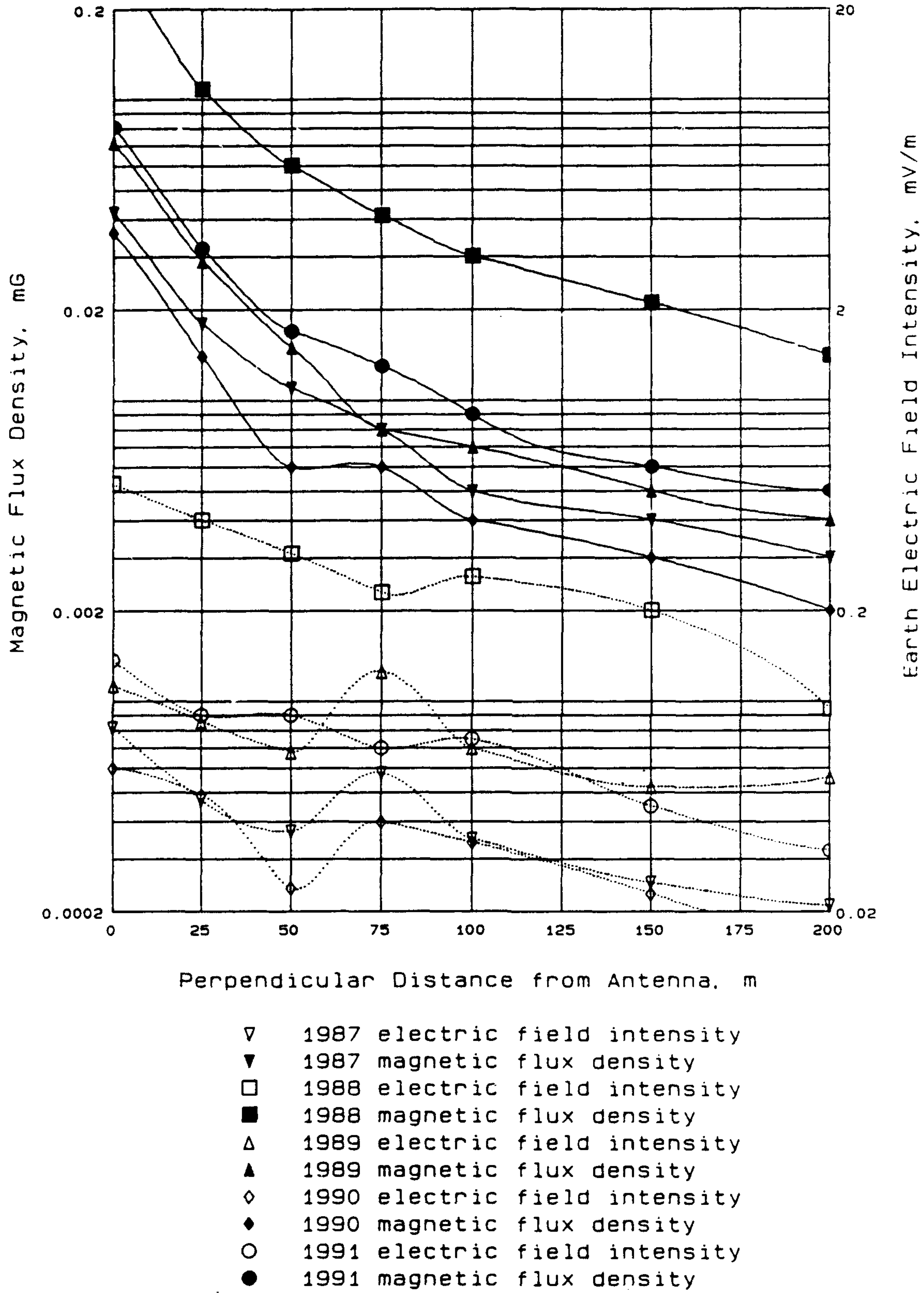


FIGURE A-17. 60 Hz MAGNETIC AND EARTH ELECTRIC FIELD PROFILES, PIRLOT ROAD; 1T1-21 THROUGH 27.

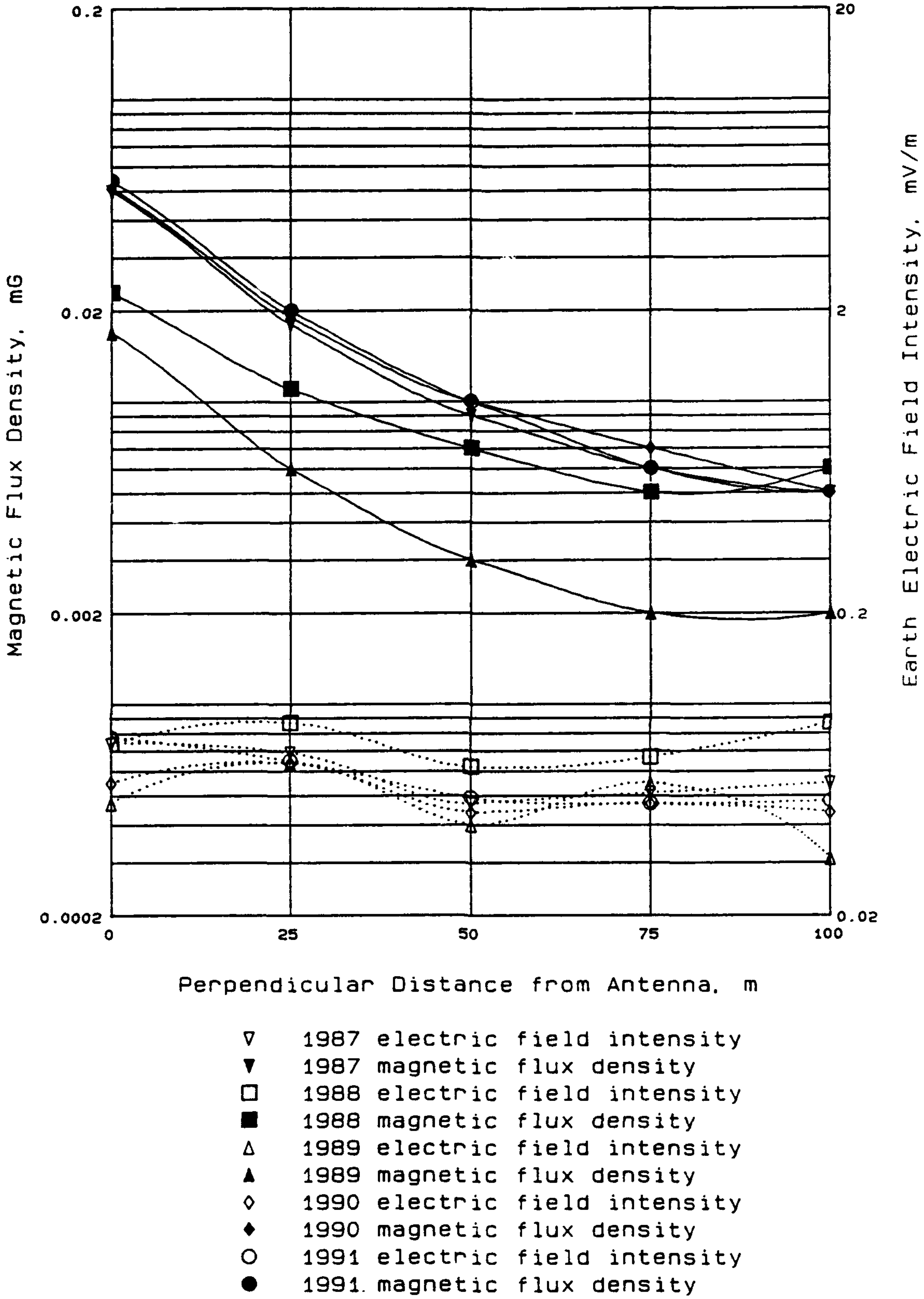


FIGURE A-18. 60 Hz MAGNETIC AND EARTH ELECTRIC FIELD PROFILES, CLEVELAND HOMESTEAD; 1T2-5 THROUGH 9.

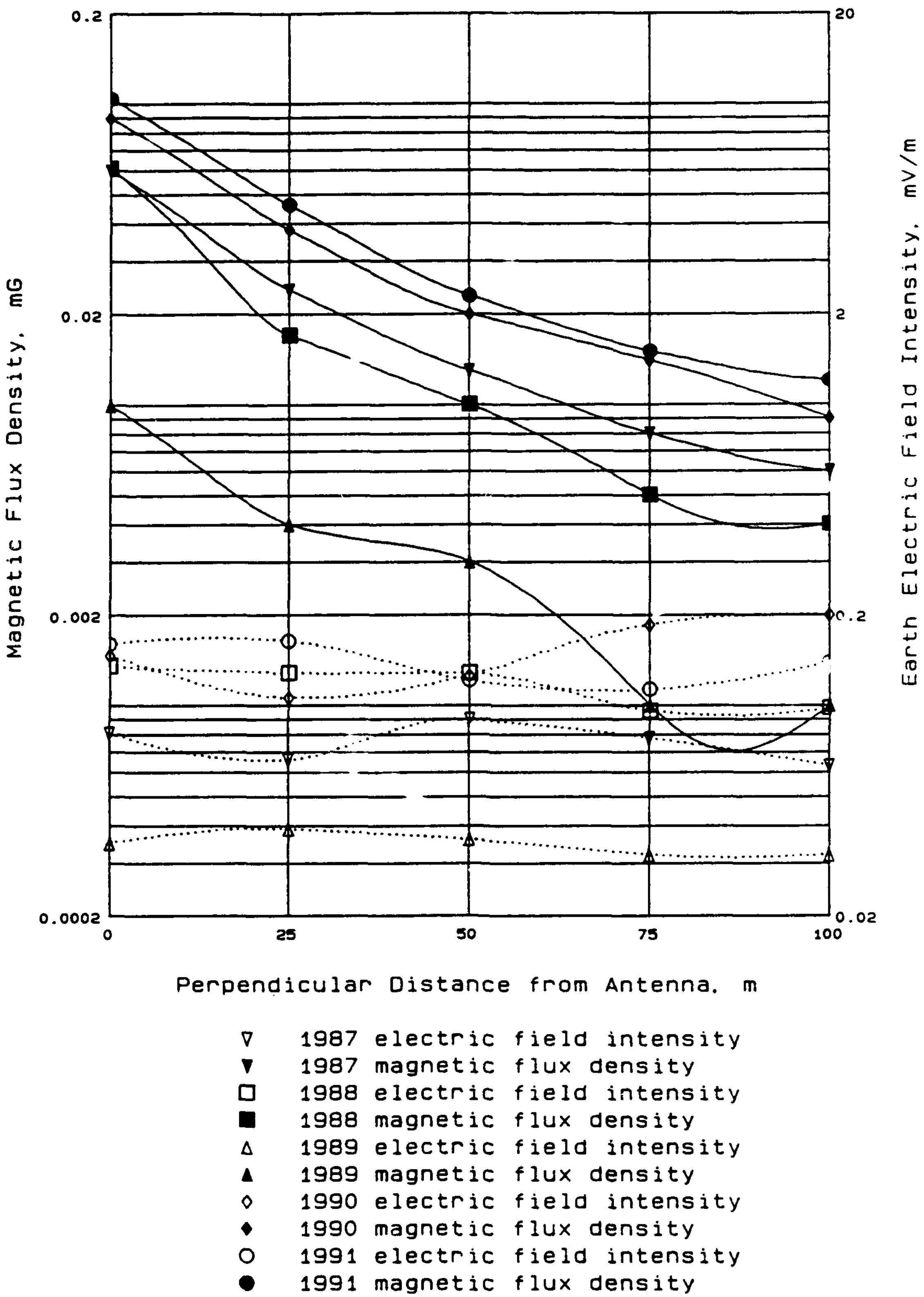


FIGURE A-19. 60 Hz MAGNETIC AND EARTH ELECTRIC FIELD PROFILES, NORTH TURNER ROAD; 1T4-5 THROUGH 9.

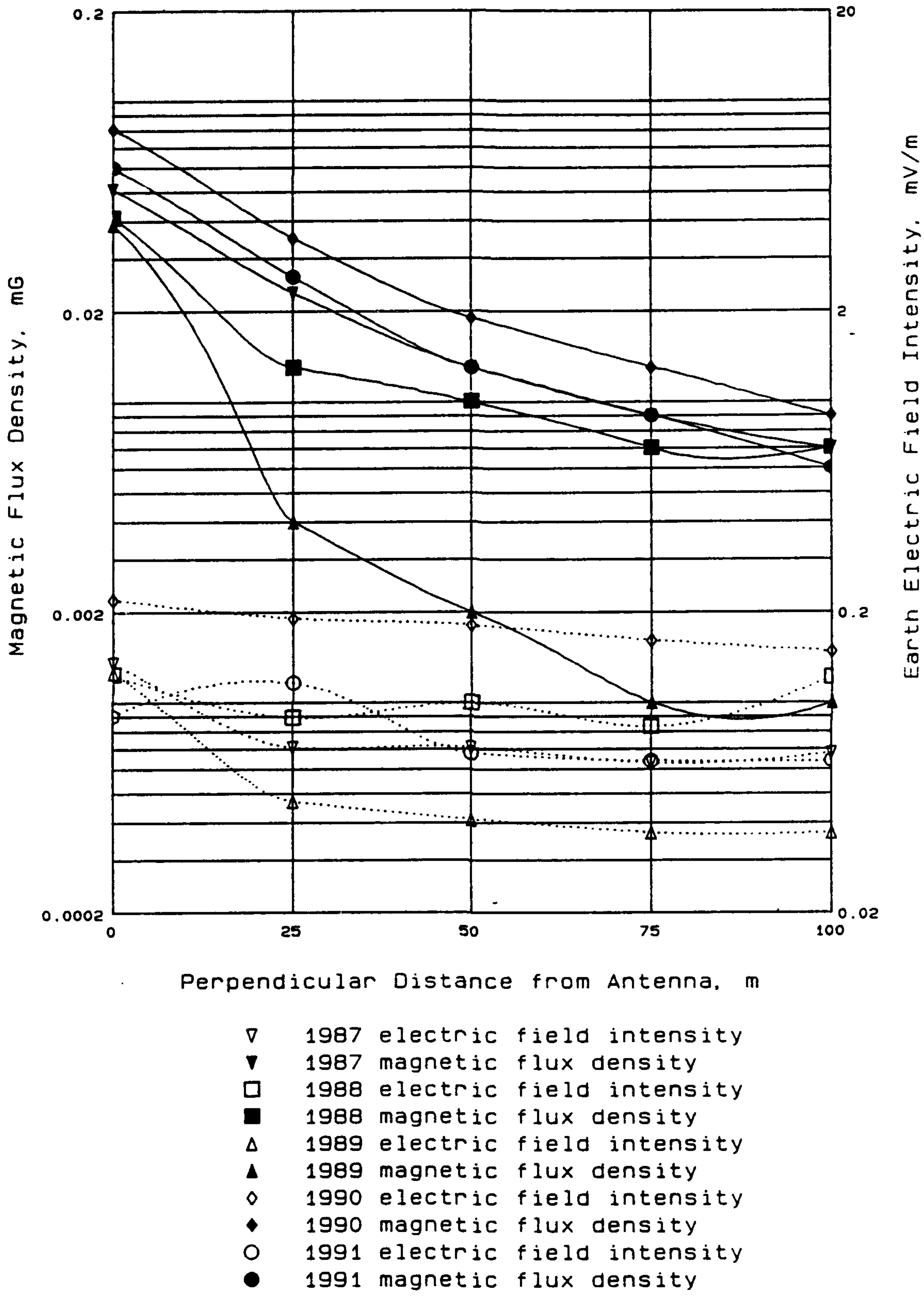


FIGURE A-20. 60 Hz MAGNETIC AND EARTH ELECTRIC FIELD PROFILES, NORTH TURNER ROAD; 1T4-10 THROUGH 14.

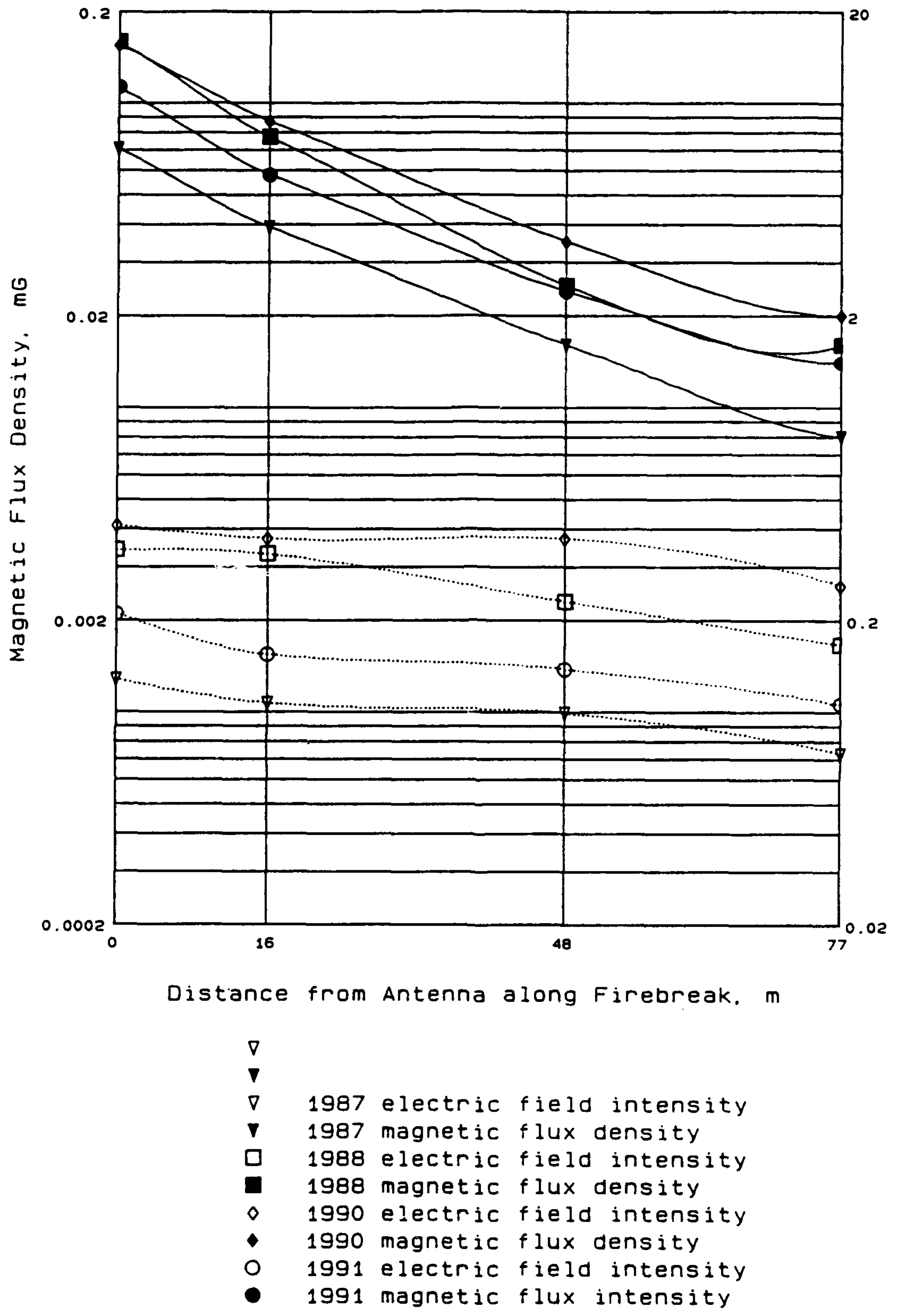


FIGURE A-21. 60 Hz MAGNETIC AND EARTH ELECTRIC FIELD PROFILES, FORD RIVER NORTH; 1T5-1, 7, 8, 4.

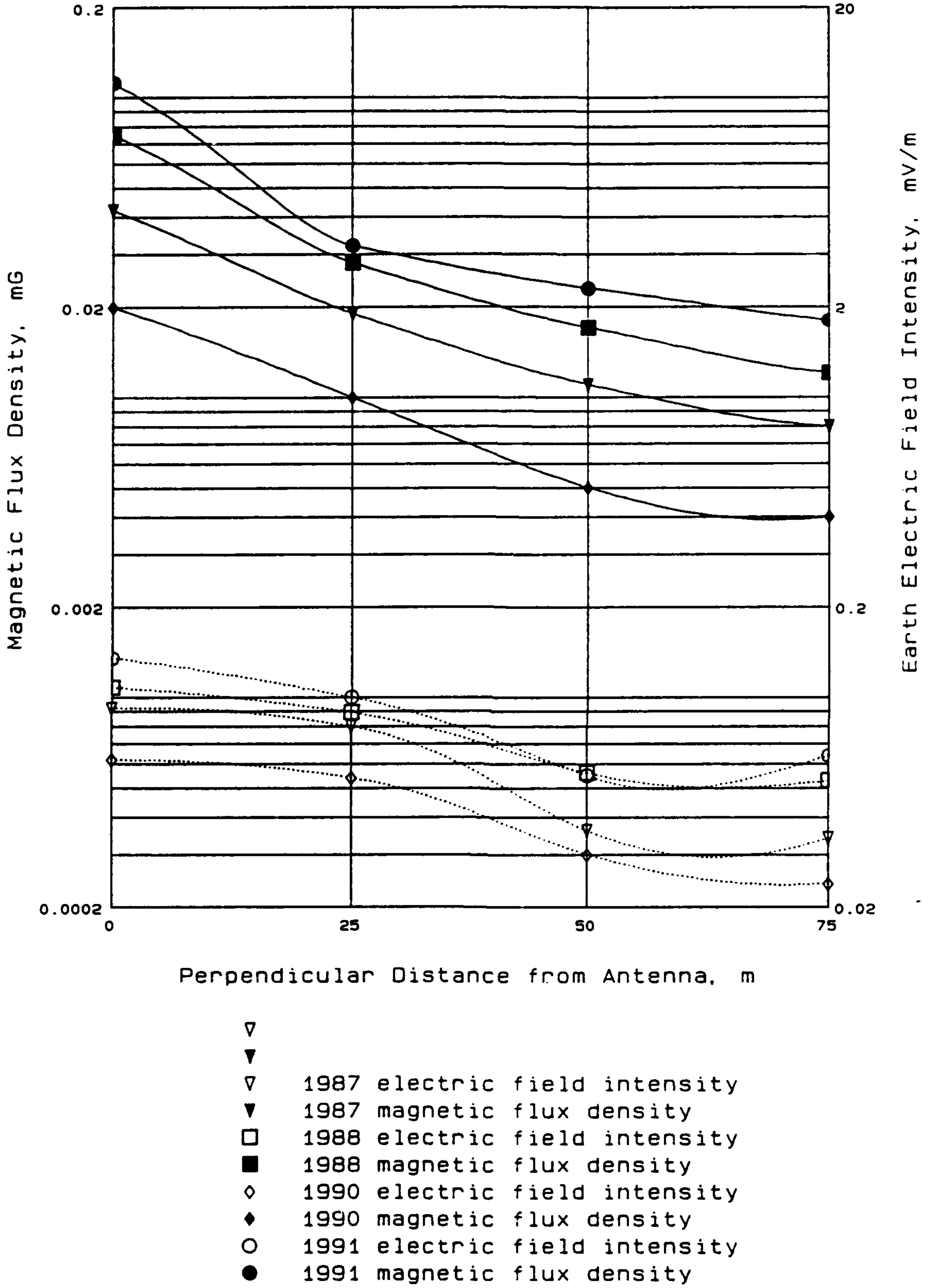


FIGURE A-22. 60 Hz MAGNETIC AND EARTH ELECTRIC FIELD PROFILES, FORD RIVER NORTH; 1T5-2, 9, 10, 6.

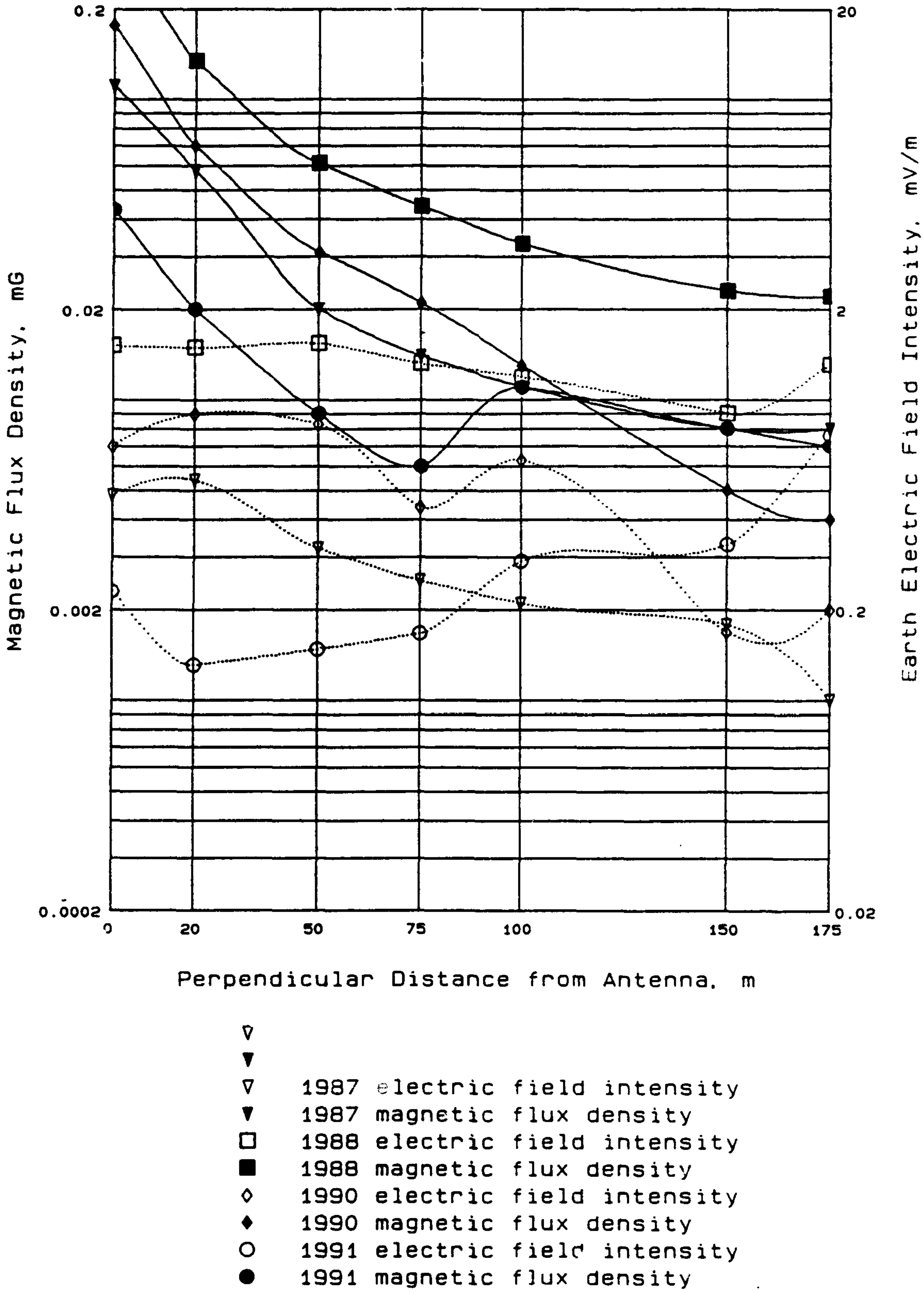


FIGURE A-23. 60 Hz MAGNETIC AND EARTH ELECTRIC FIELD PROFILES, FORD RIVER SOUTH; 1T6-2, 1, 3, 4, 5, 6, 7.

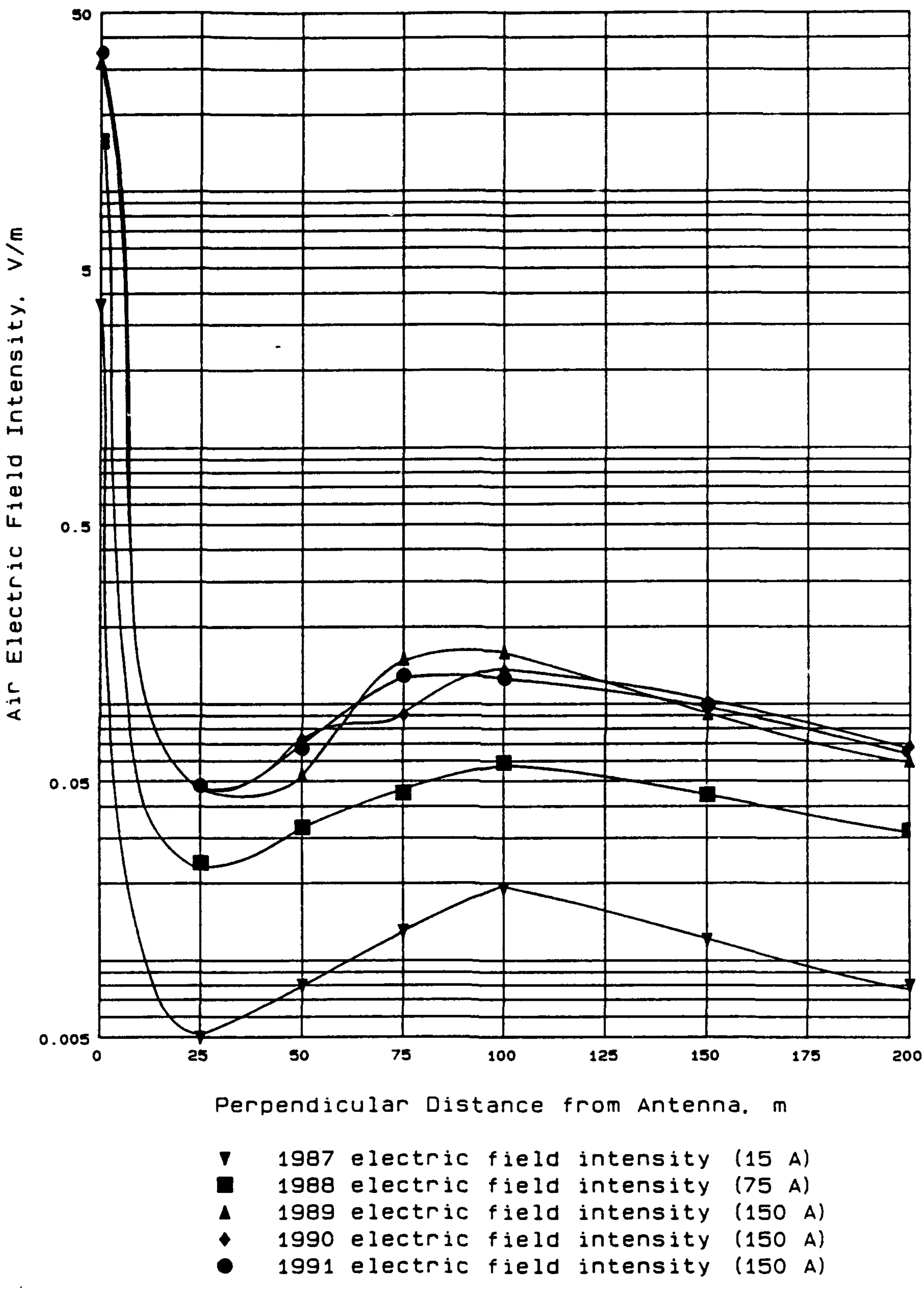


FIGURE A-24. 76 Hz AIR ELECTRIC FIELD PROFILES, PIRLOT ROAD; 1T1-21 THROUGH 27.

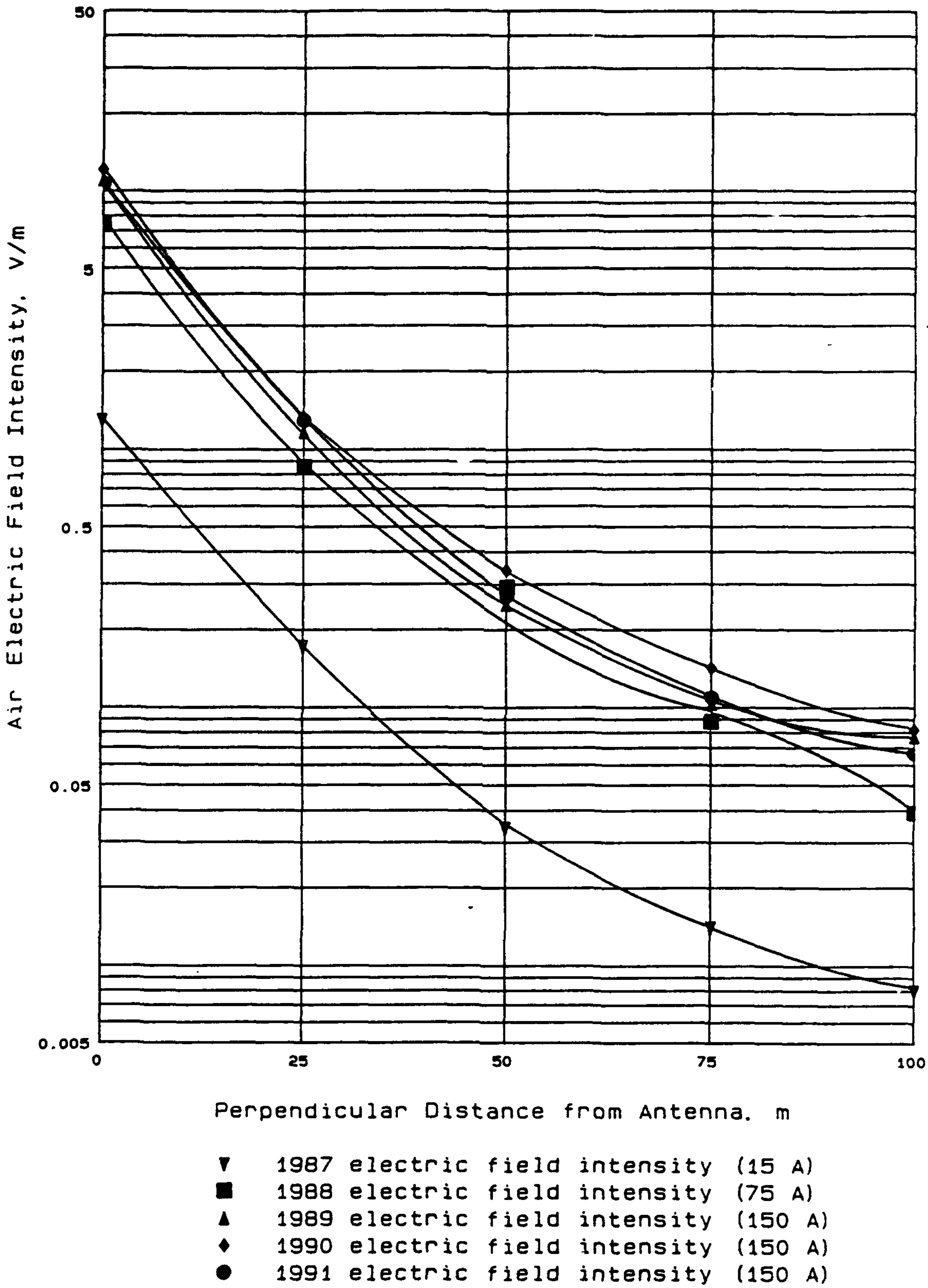


FIGURE A-25. 76 Hz AIR ELECTRIC FIELD PROFILES, CLEVELAND HOMESTEAD; 1T2-5 THROUGH 9.

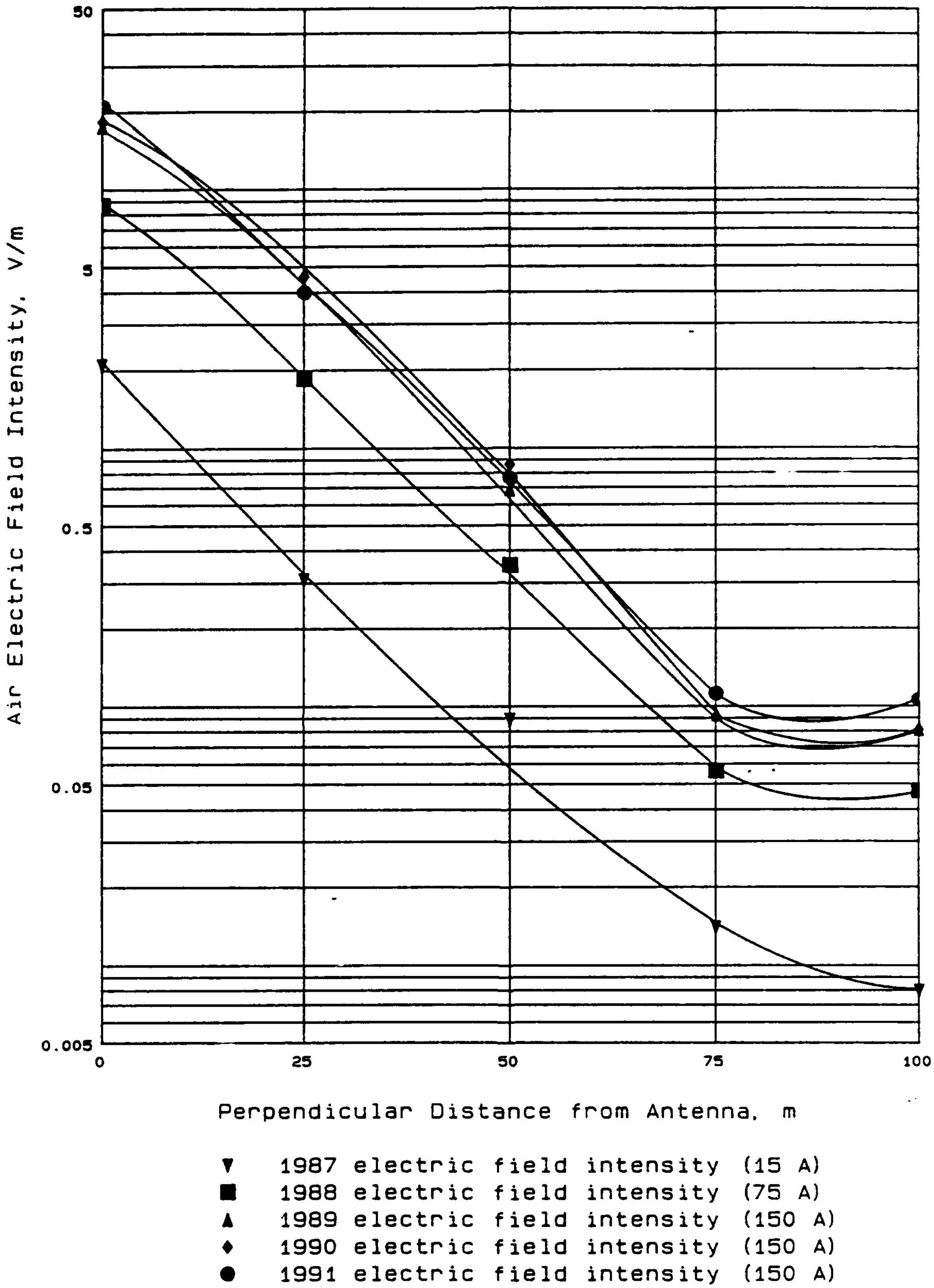
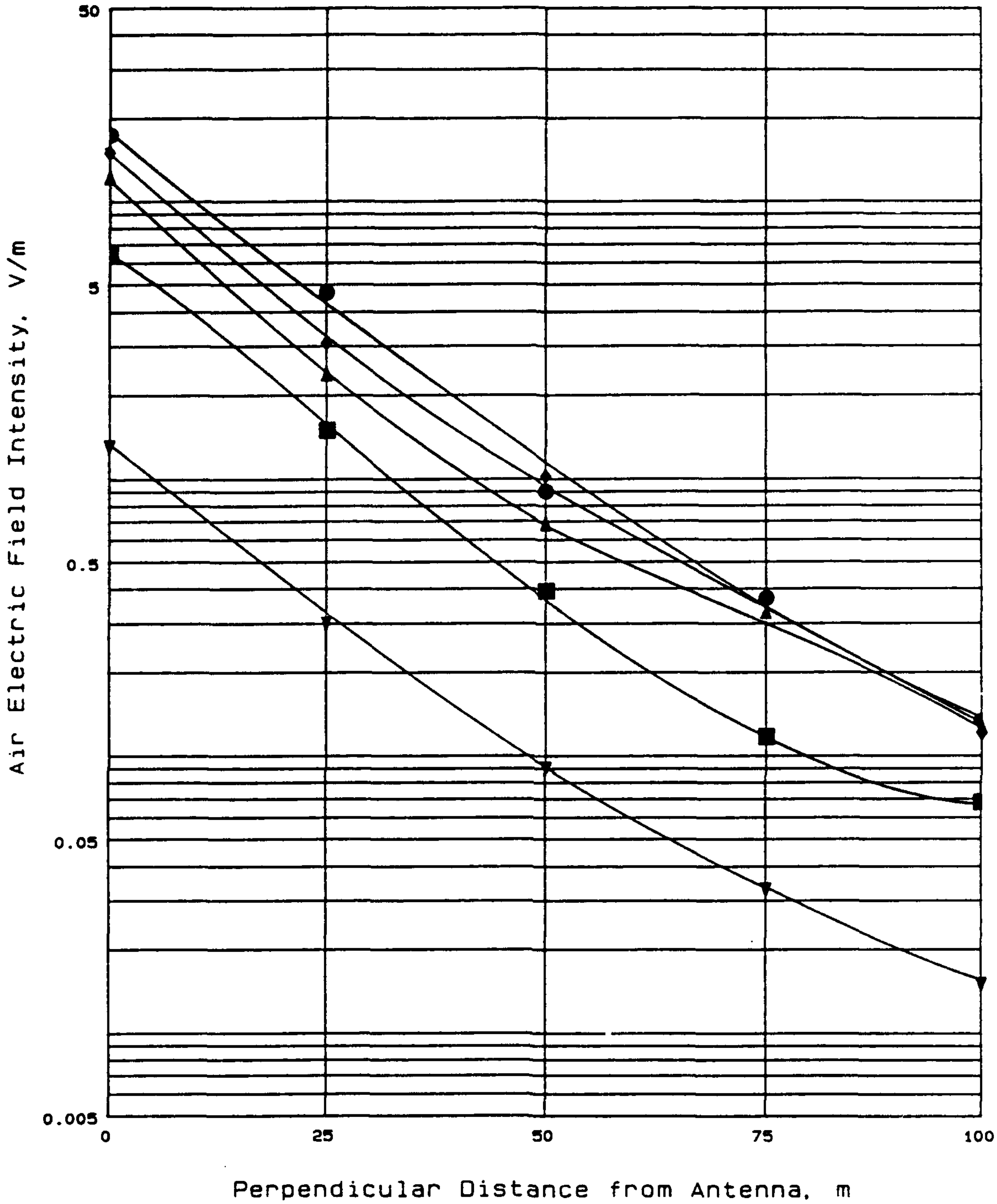
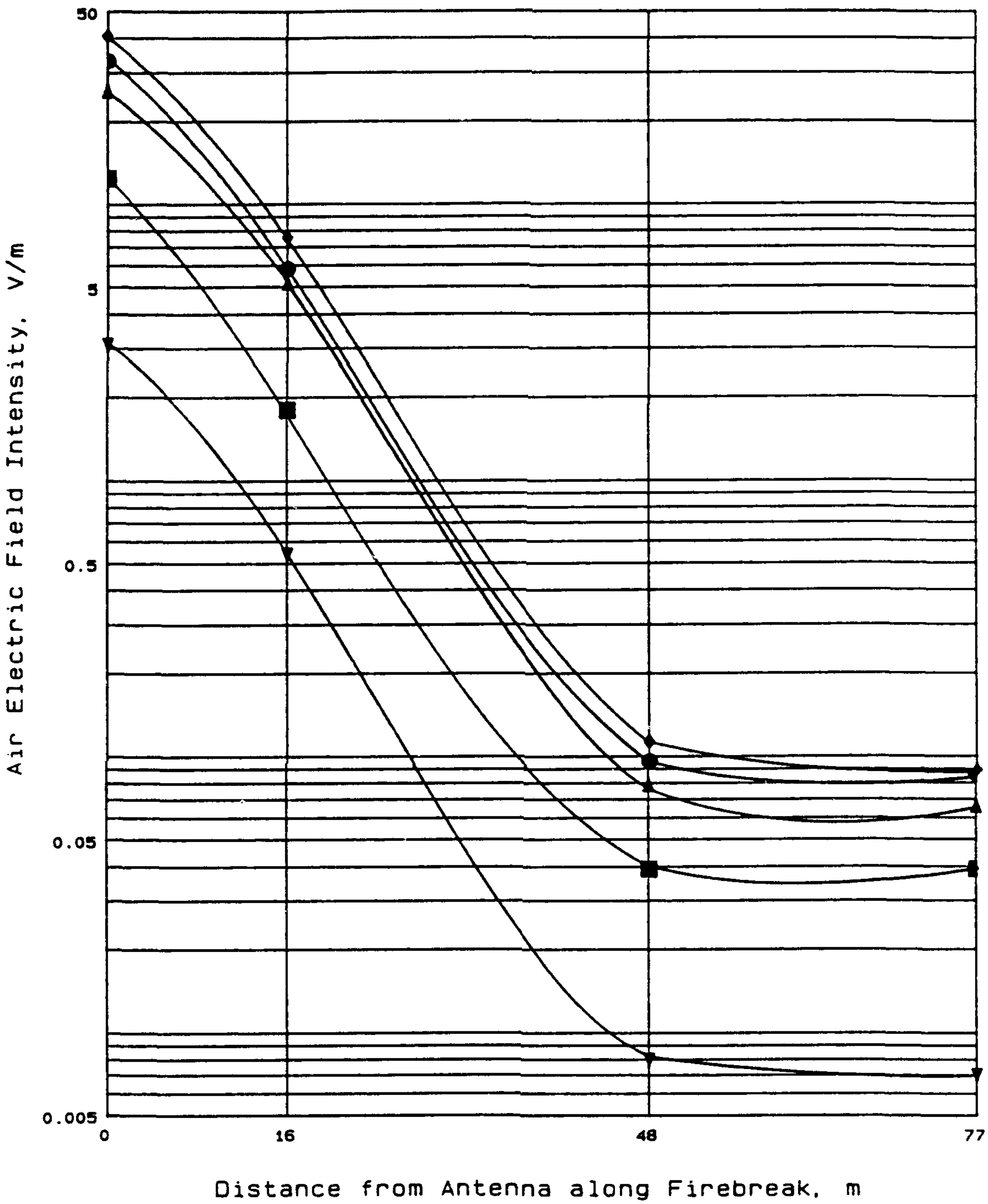


FIGURE A-26. 76 Hz AIR ELECTRIC FIELD PROFILES, NORTH TURNER ROAD; 1T4-5 THROUGH 9.



▼ 1987 electric field intensity (15 A)
■ 1988 electric field intensity (75 A)
▲ 1989 electric field intensity (150 A)
♦ 1990 electric field intensity (150 A)
● 1991 electric field intensity (150 A)

FIGURE A-27. 76 Hz AIR ELECTRIC FIELD PROFILES, NORTH TURNER ROAD; 1T4-10 THROUGH 14.



▼ 1987 electric field intensity (15 A)
■ 1988 electric field intensity (75 A)
▲ 1989 electric field intensity (150 A)
♦ 1990 electric field intensity (150 A)
● 1991 electric field intensity (150 A)

FIGURE A-28. 76 Hz AIR ELECTRIC FIELD PROFILES, FORD RIVER NORTH; 1T5-1, 7, 8, 4.

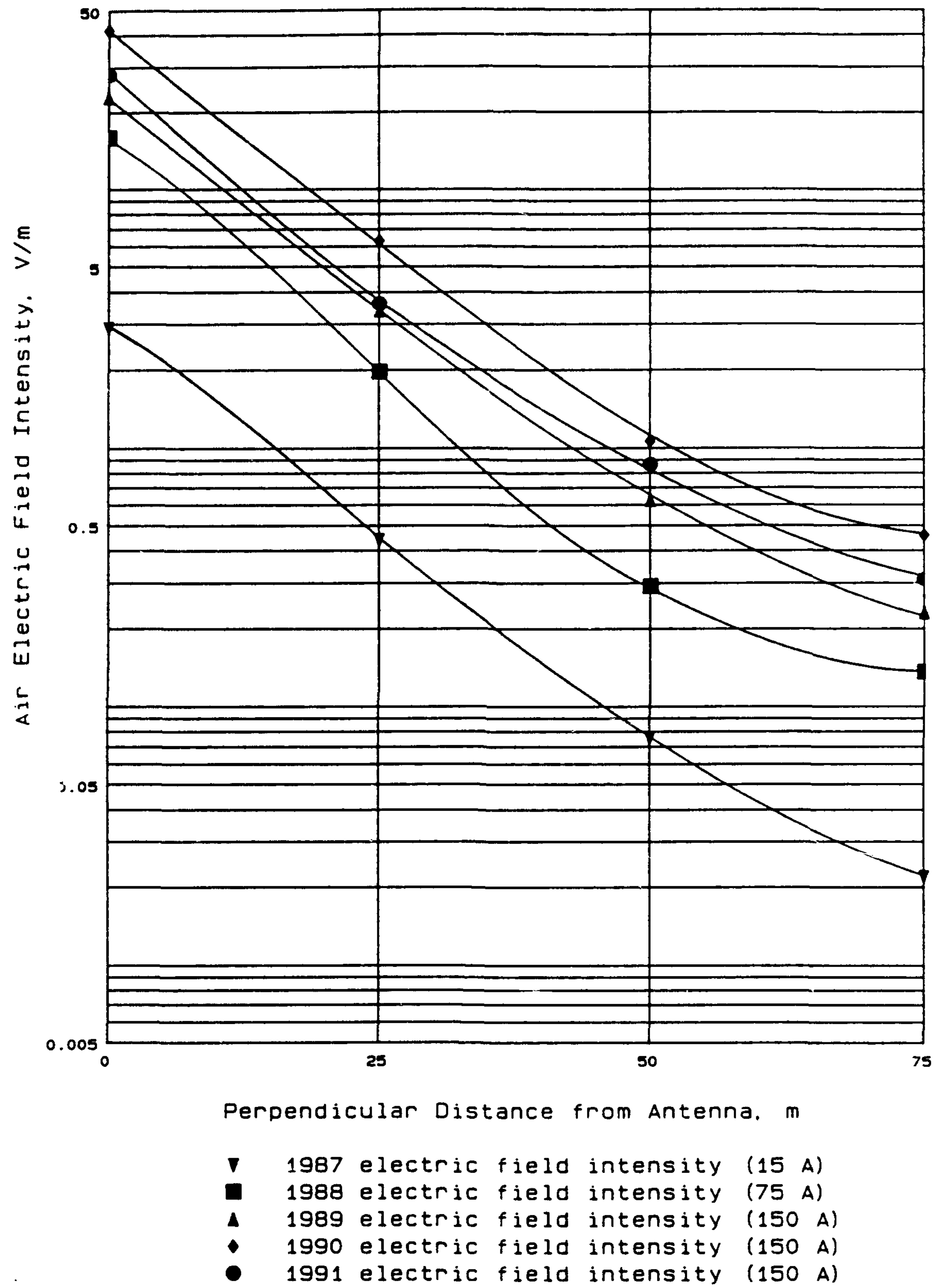


FIGURE A-29. 76 Hz AIR ELECTRIC FIELD PROFILES, FORD RIVER NORTH; 1T5-2, 9, 10, 6.

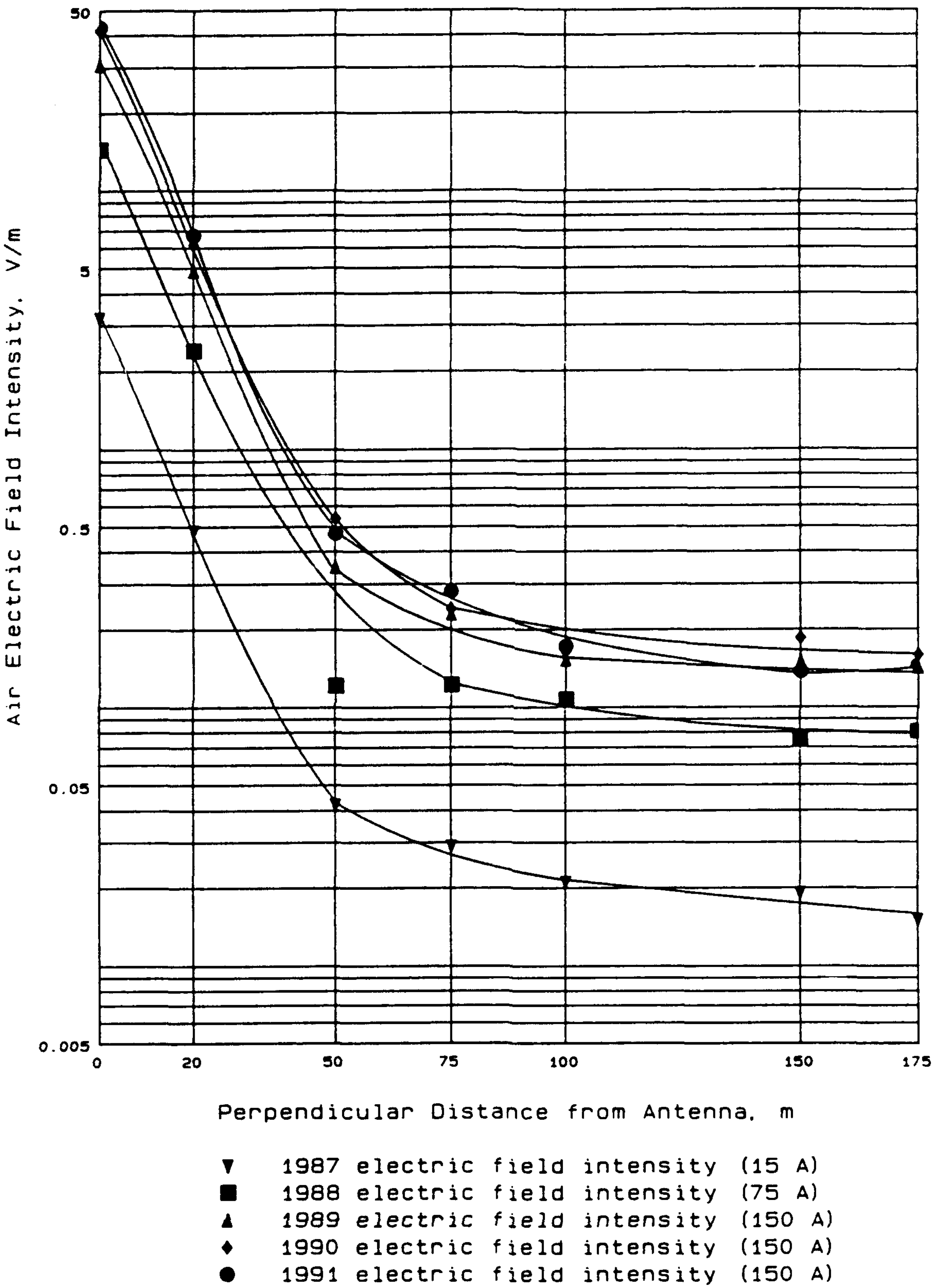


FIGURE A-30. 76 Hz AIR ELECTRIC FIELD PROFILES, FORD RIVER SOUTH; 1T6-2, 1, 3, 4, 5, 6, 7.

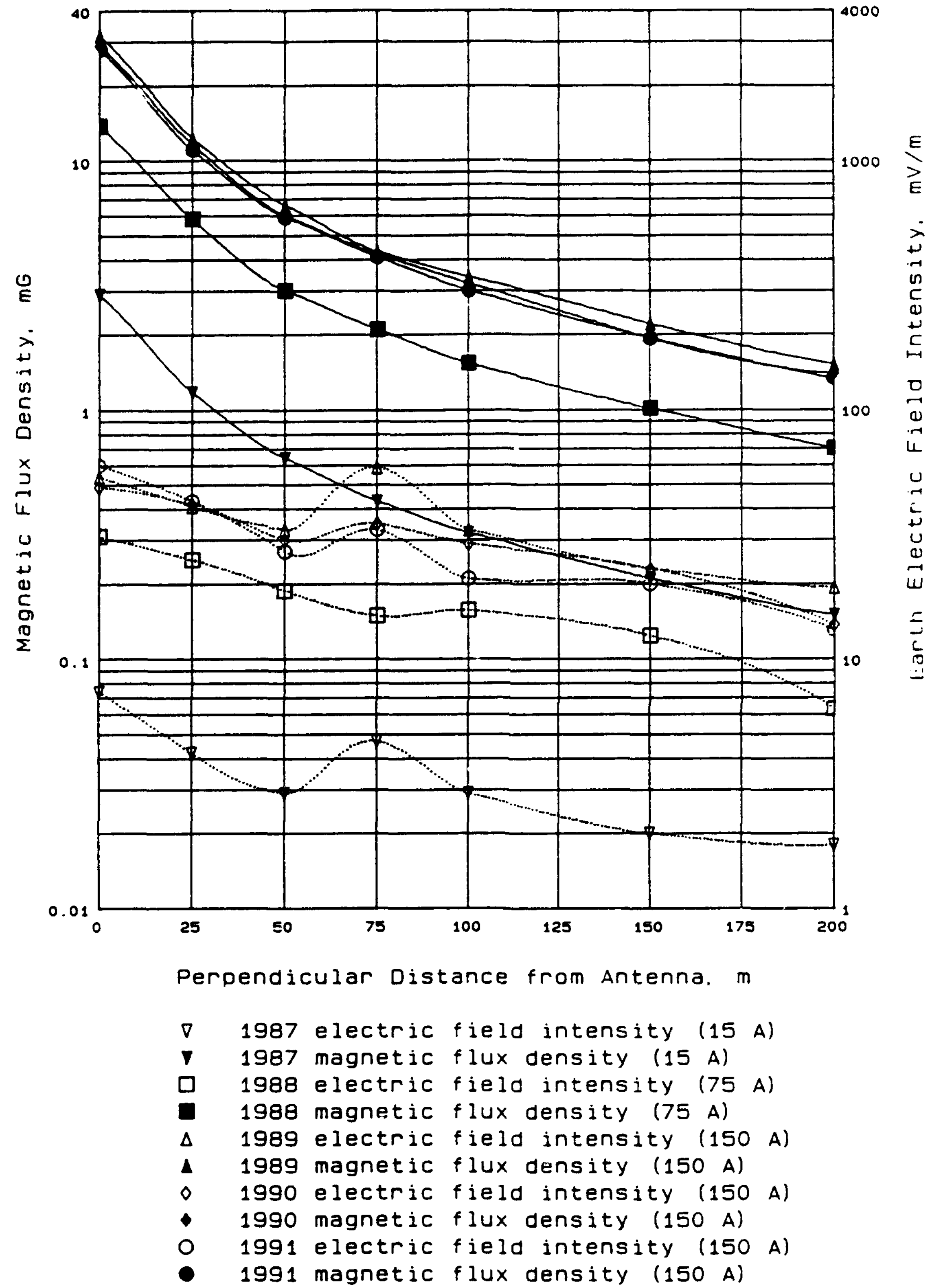


FIGURE A-31. 76 Hz MAGNETIC AND EARTH ELECTRIC FIELD PROFILES, PIRLOT ROAD; 1T1-21 THROUGH 27.

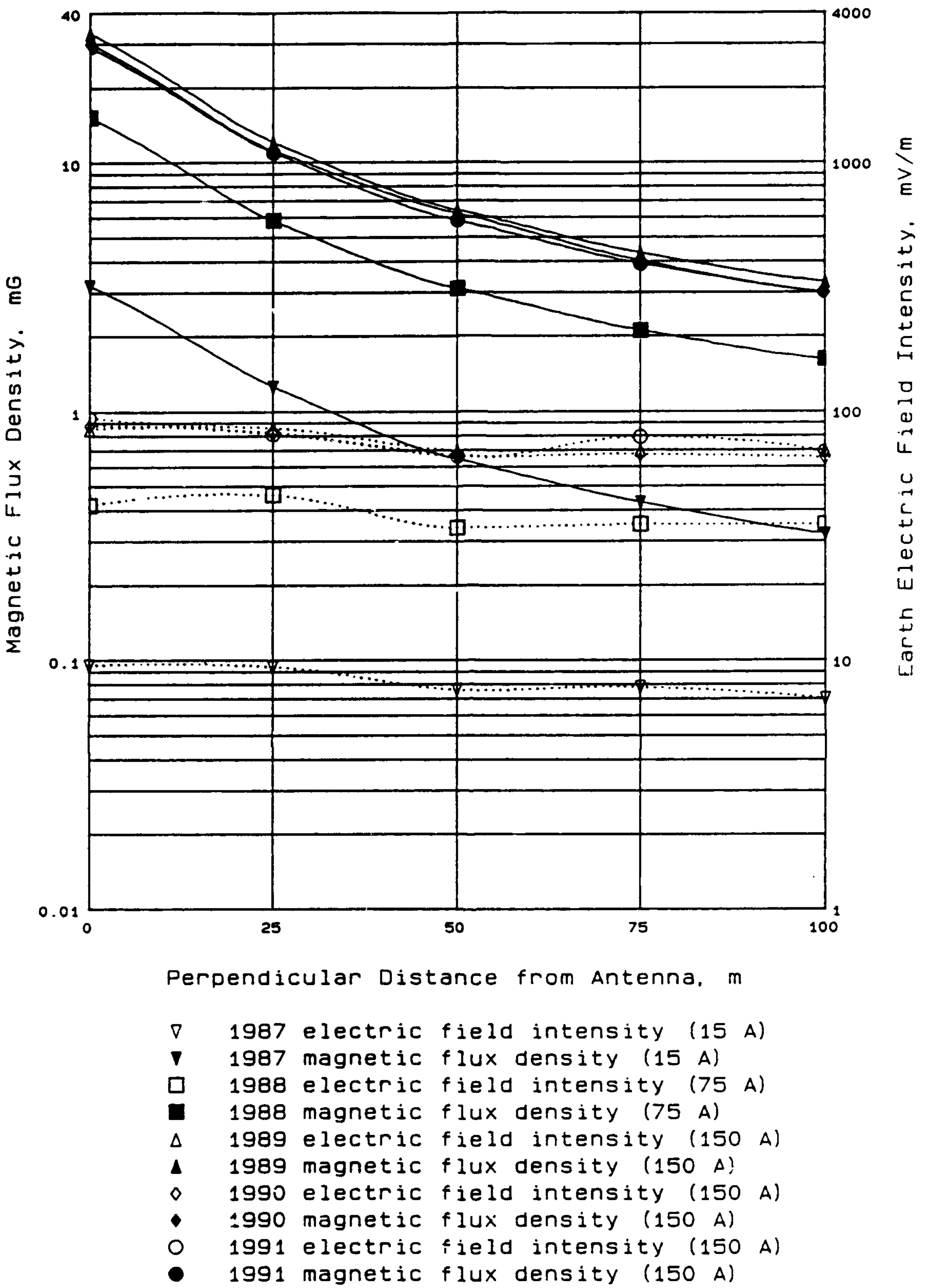


FIGURE A-32. 76 Hz MAGNETIC AND EARTH ELECTRIC FIELD PROFILES, CLEVELAND HOMESTEAD; 1T2-5 THROUGH 9.

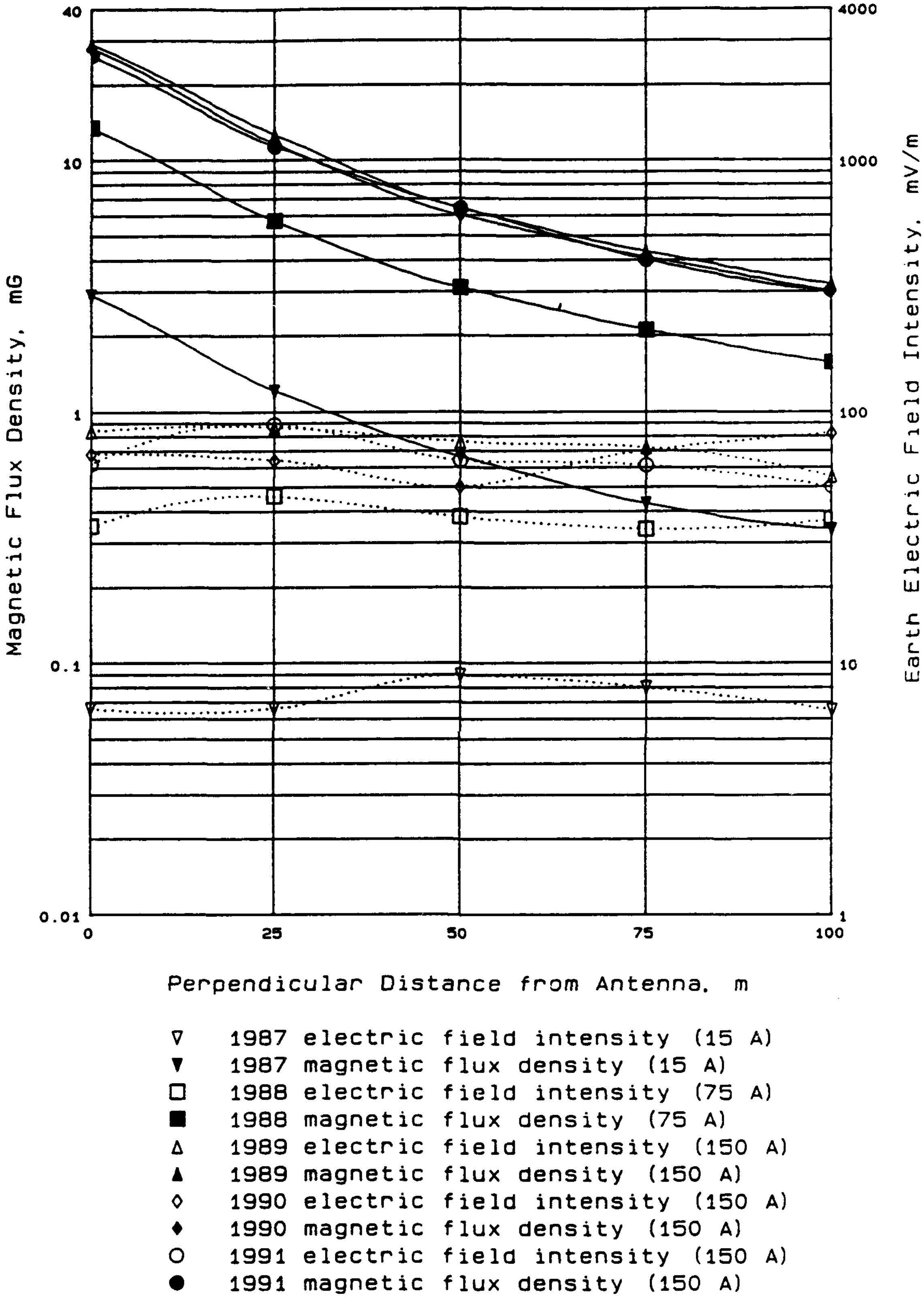


FIGURE A-33. 76 Hz MAGNETIC AND EARTH ELECTRIC FIELD PROFILES, NORTH TURNER ROAD; 1T4-5 THROUGH 9.

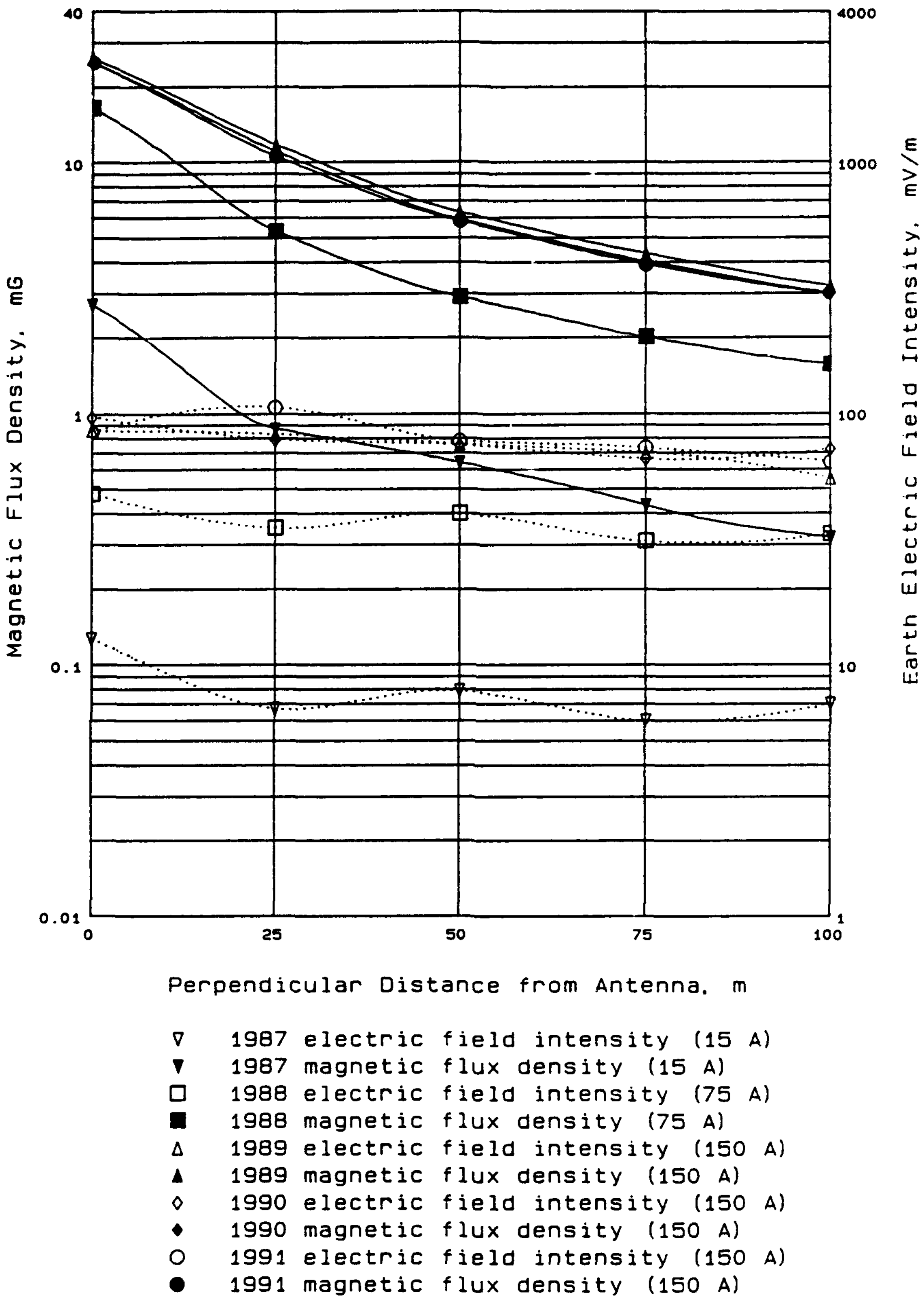


FIGURE A-34. 76 Hz MAGNETIC AND EARTH ELECTRIC FIELD PROFILES, NORTH TURNER ROAD; 1T4-10 THROUGH 14.

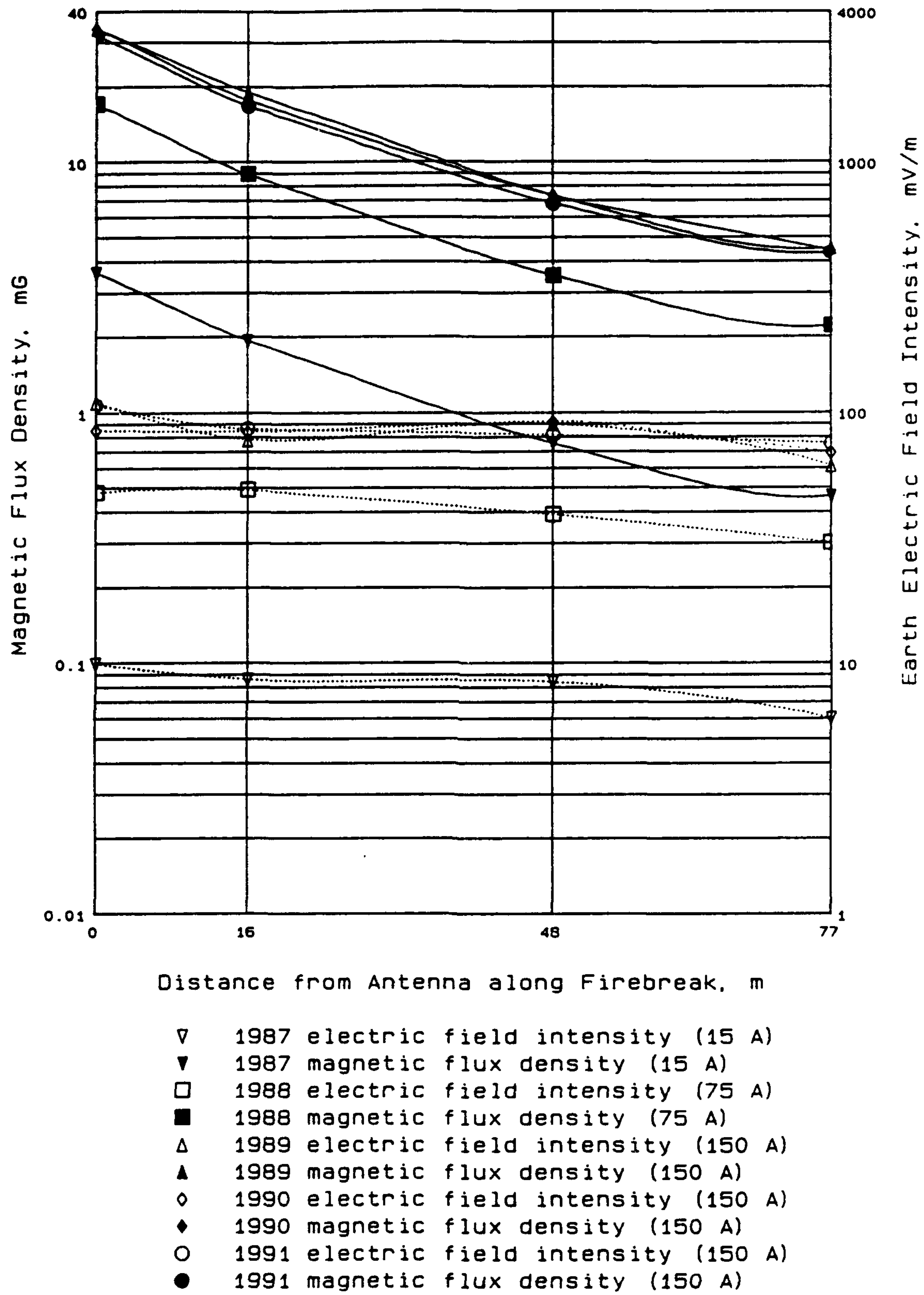


FIGURE A-35. 76 Hz MAGNETIC AND EARTH ELECTRIC FIELD PROFILES, FORD RIVER NORTH; 1T5-1, 7, 8, 4.

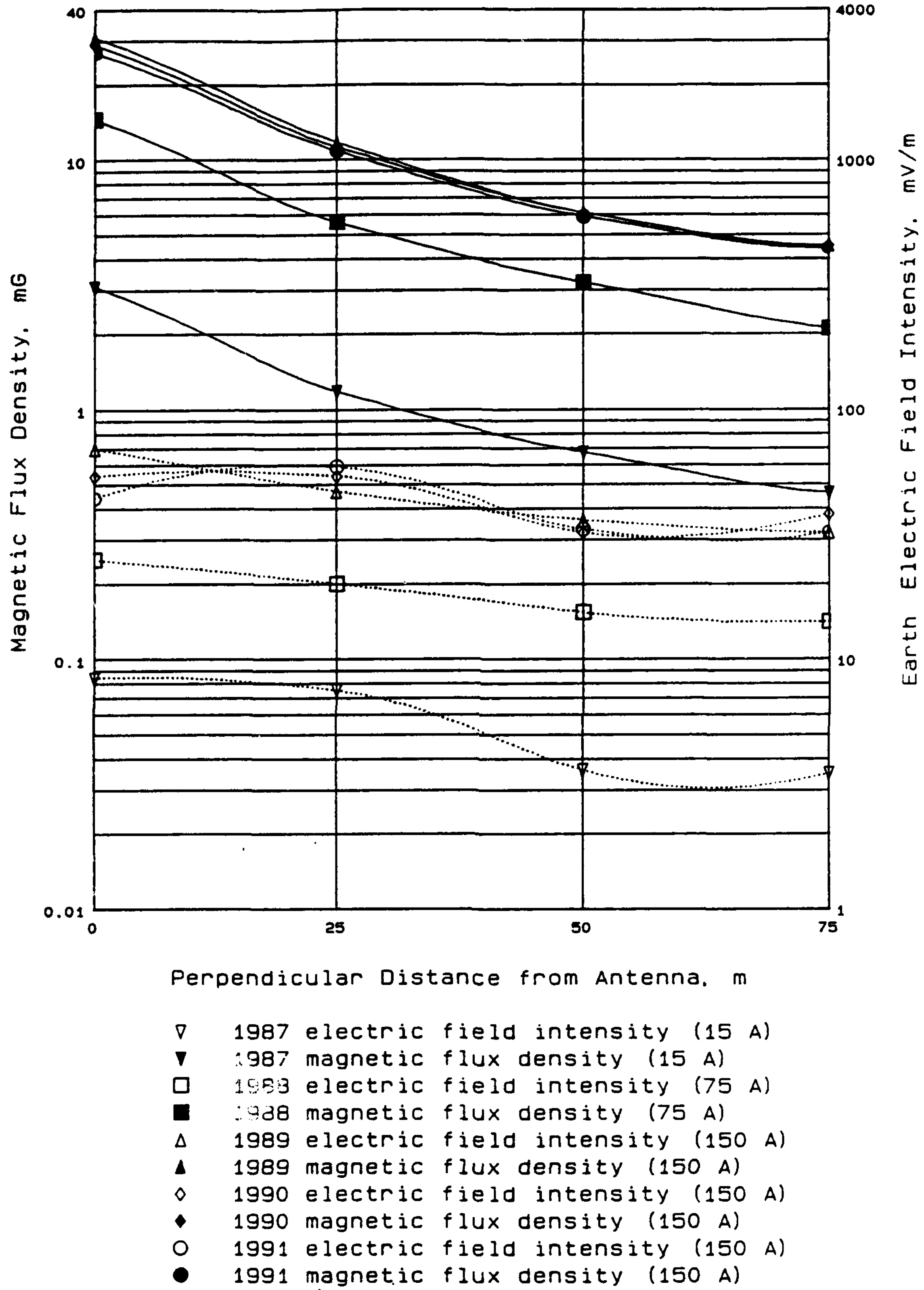


FIGURE A-36. 76 Hz MAGNETIC AND EARTH ELECTRIC FIELD PROFILES, FORD RIVER NORTH; 1T5-2, 9, 10, 6.

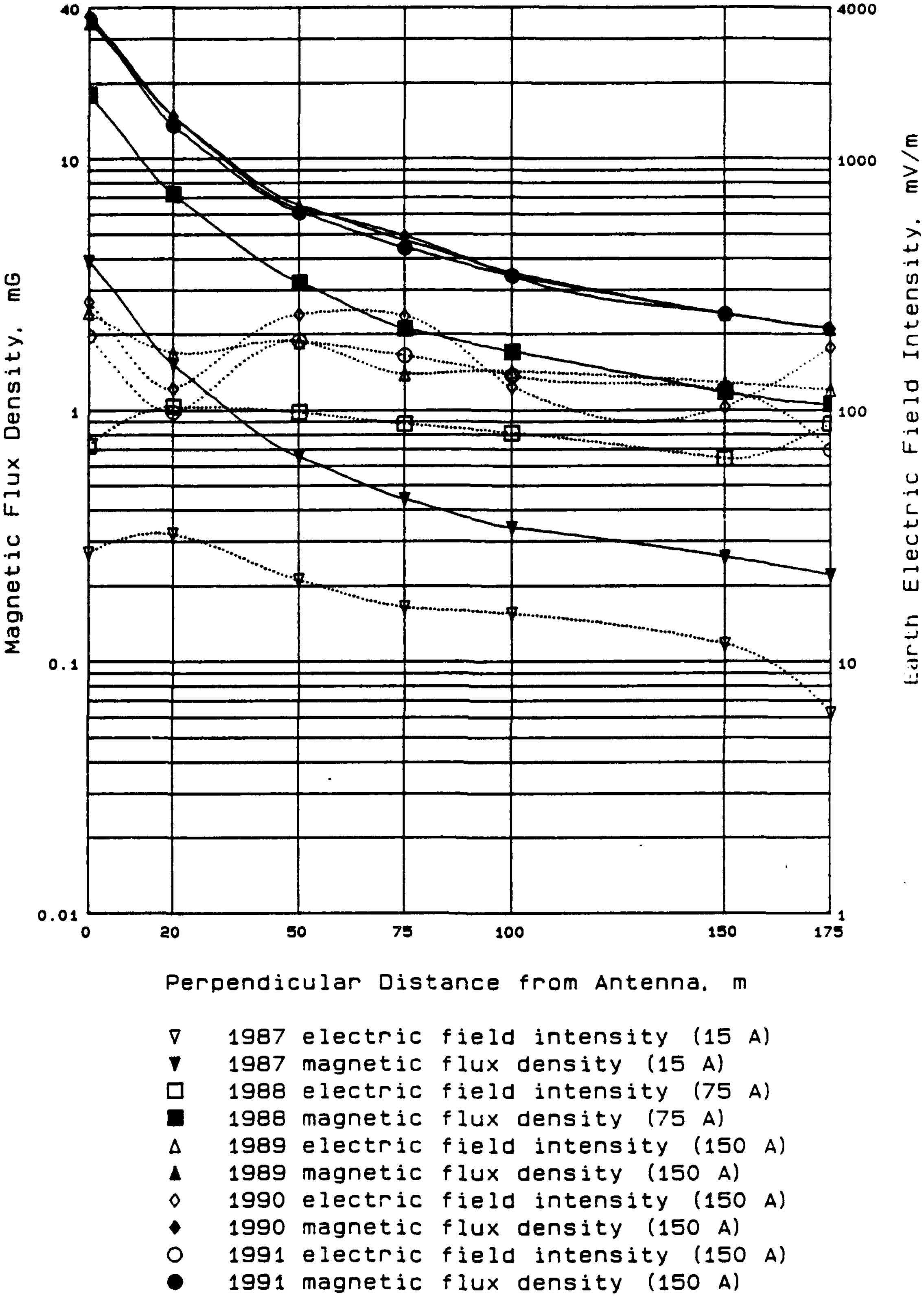


FIGURE A-37. 76 Hz MAGNETIC AND EARTH ELECTRIC FIELD PROFILES, FORD RIVER NORTH; 1T6-2, 1, 3, 4, 5, 6, 7.

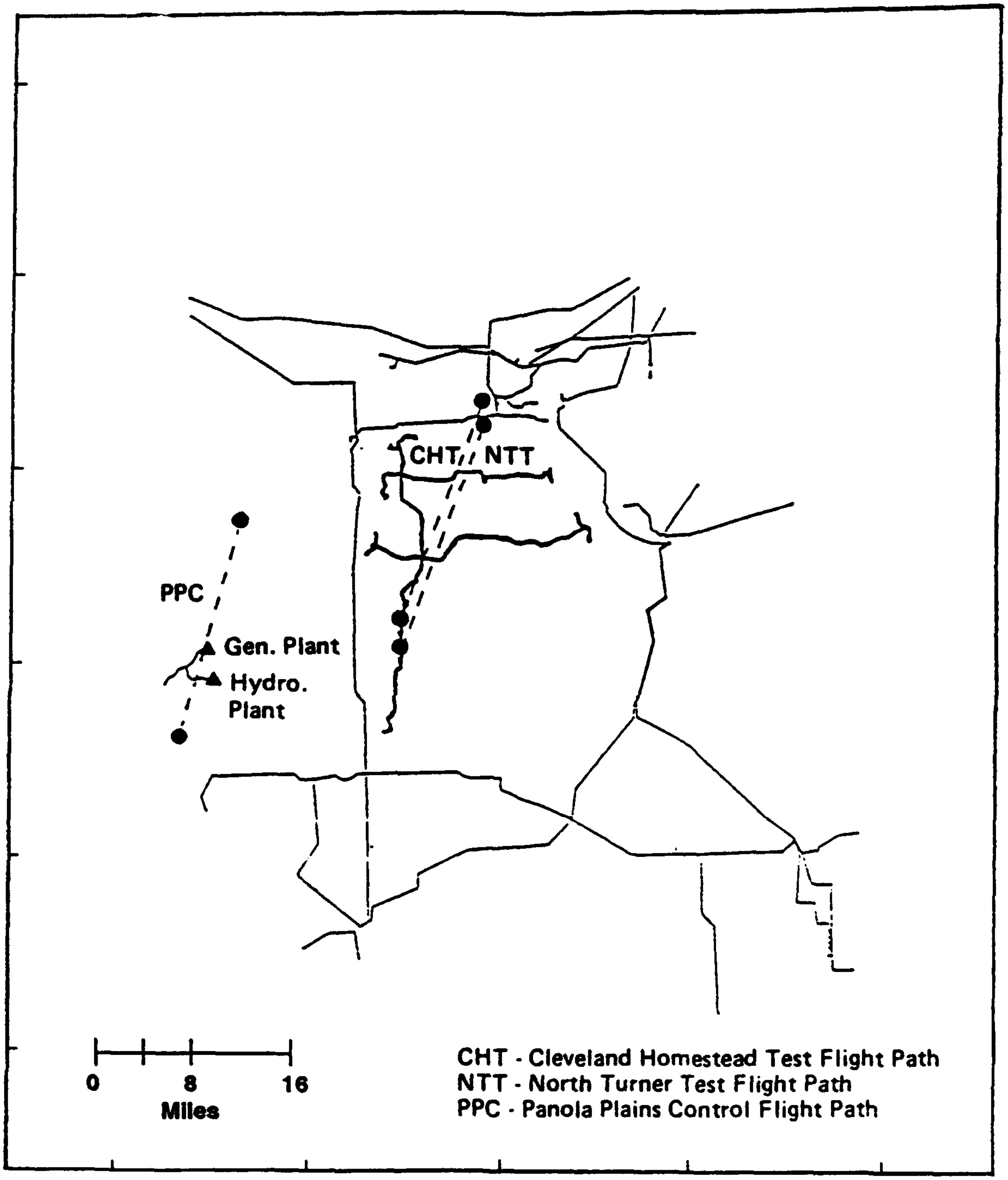


FIGURE A-38. BIRD DISPLACEMENT FLIGHT PATH LOCATIONS RELATIVE TO HIGH-VOLTAGE 60 Hz TRANSMISSION LINES.

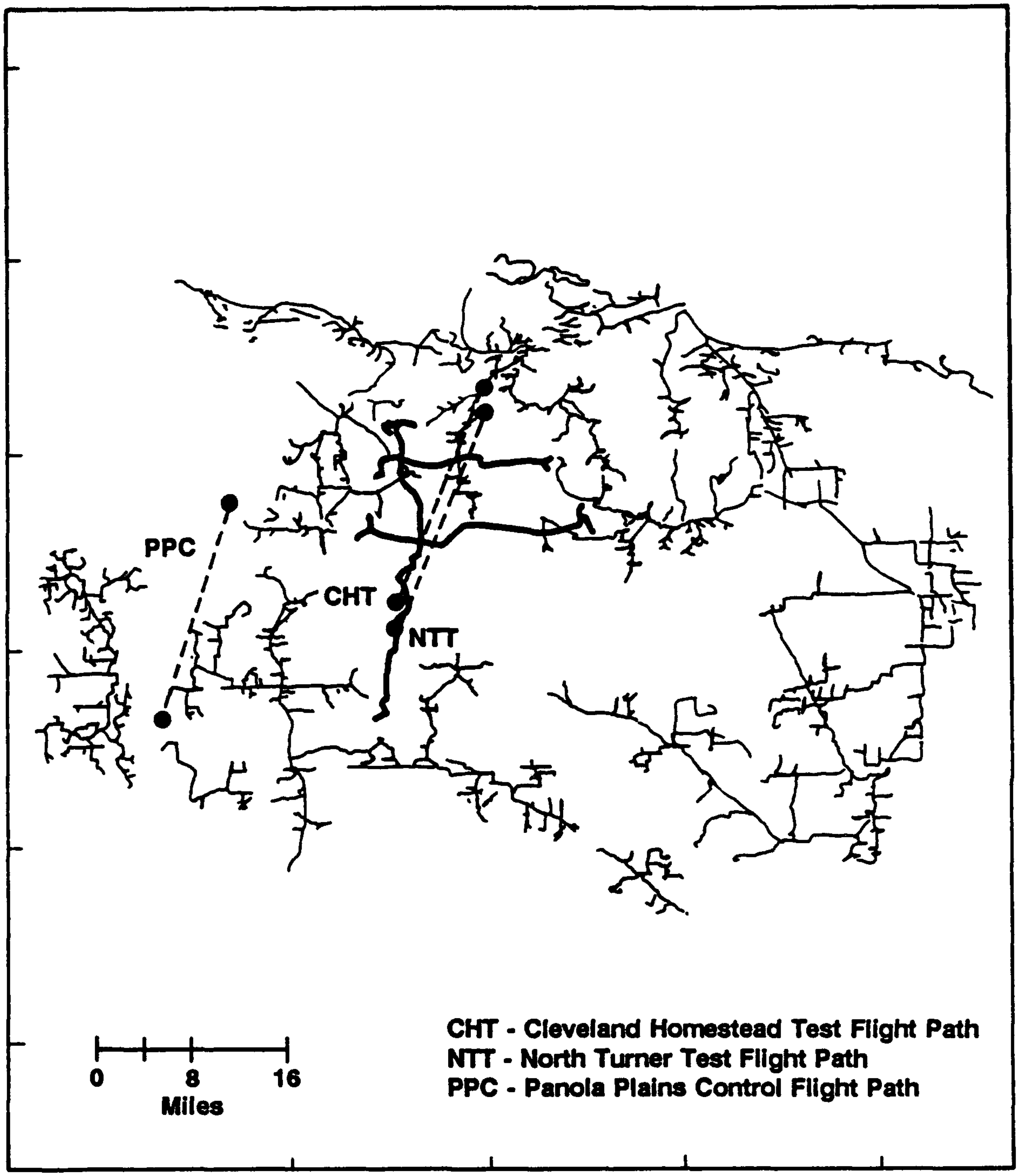


FIGURE A-39. BIRD DISPLACEMENT FLIGHT PATH LOCATIONS RELATIVE TO 60 Hz POWER DISTRIBUTION LINES.

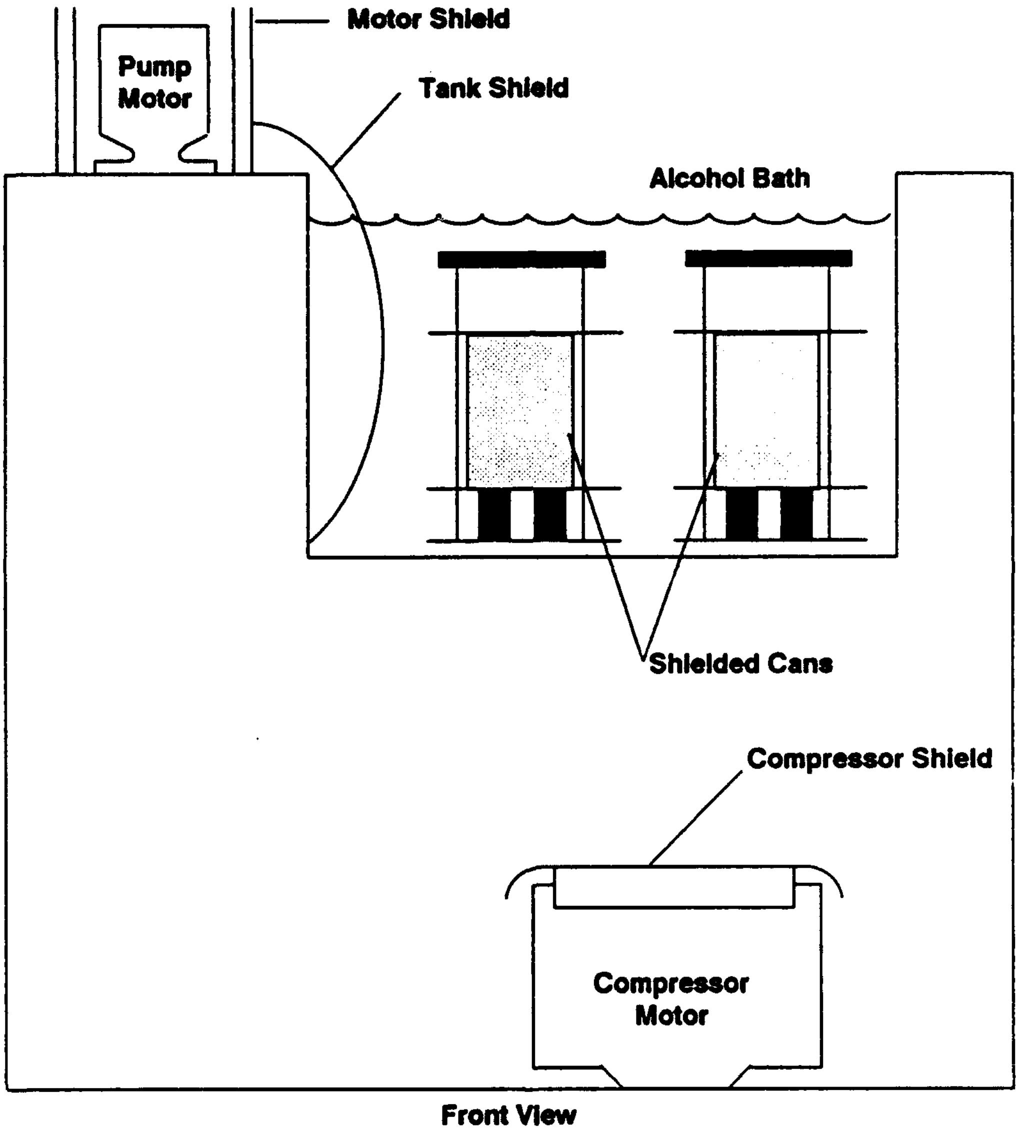


FIGURE A-40. MAGNETIC SHIELD LOCATIONS AT THE METABOLIC COOLING BATH.

TABLE A-3. 60 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Small Mammals and Nesting Birds Studies
(page 1 of 4)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991
1C1-2	<	<	<	--	--	--	--	--	--
1C1-3	-	-	<	<	<	<	<	<[d]	<[d]
1C1-4	-	-	-	<	<	<	<	<[d]	<[d]
1C3-1	<	<	<	<	<	<	<	<[d]	<[d]
1C3-2	<	<	--	--	--	--	--	--	--
1C3-3	-	-	-	<	<	<	<	<[d]	<[d]
1C4-1	-	0.001	<	<	<	<	<	<[d]	<[d]
1C4-2	-	<0.001	<	--	--	--	--	--	--
1C4-3	-	<0.001	<	<	--	--	--	--	--
1C4-4	-	-	<	<	<	<	<	<[d]	<[d]
1C4-5	-	-	-	-	<	<	<	<[d]	<[d]
1D3-1	-	-	-	<	<	<	<	<[d]	<[d]
1C6-1	-	0.001	<	<	<	<	<	<[d]	<[d]
1C6-3	-	-	<	<	<	<	<	<[d]	<[d]
1C6-4	-	-	<	<	<	<	<	<[d]	<[d]
1L4-1	-	-	-	-	-	<	<	<[d]	<[d]

a = antennas not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 A current.

\- = measurement point not established.
-- = measurement point dropped.
/ = measurement not taken.
\# = measurement precluded by antenna operation.
< = measurement est. <0.001 V/m based on earth E-field.

TABLE A-3. 60 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Small Mammals and Nesting Birds Studies
(page 2 of 4)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991
1T1-1	0.001	<	<	--	--	--	--	--	--
1T1-3	-	<	<	--	--	--	--	--	--
1T1-4	-	<	<	--	--	--	--	--	--
1T1-10	-	<	<	--	--	--	--	--	--
1T1-12	-	-	<	--	--	--	--	--	--
1T1-13	-	-	<	--	--	--	--	--	--
1T1-14	-	-	-	<	<	<	<	<[b]	<[c]
1T1-15	-	-	-	<	<	<	#	<[b]	<[c]
1T1-16	-	-	-	<	<	<	#	<[b]	<[c]
1T1-17	-	-	-	<	<	<	#	<[b]	<[b]
1T1-18	-	-	-	<	<	<	#	<[b]	<[b]
1T1-19	-	-	-	<	<	<	#	<[b]	<[b]
1T1-20	-	-	-	<	<	<	#	<[b]	<[b]
1T1-28	-	-	-	-	-	<	#	<[b]	<[b]
1T1-29	-	-	-	-	-	<	#	<[b]	<[b]
1T1-30	-	-	-	-	-	<	#	<[b]	<[b]
1T1-31	-	-	-	-	-	<	#	<[b]	<[b]
1T1-21	-	-	-	<	0.086	0.49	0.109	0.076[b]	/
1T1-22	-	-	-	<	<0.001	<	<0.001	<0.001[b]	/
1T1-23	-	-	-	<	<	<	<0.001	<[b]	/
1T1-24	-	-	-	<	<	<	<	<[b]	/
1T1-25	-	-	-	<	<	<	<	<[b]	/
1T1-26	-	-	-	<	<	<	<	<[b]	/
1T1-27	-	-	-	<	<	<	<	<[b]	/

a = not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 A current.

\- = measurement point not established.
-- = measurement point dropped.
/ = measurement not taken.
= measurement precluded by antenna operation.
< = measurement est. <0.001 V/m based on earth E-field.

TABLE A-3. 60 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Small Mammals and Nesting Birds Studies
(page 3 of 4)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991
1T2-1	<0.001	0.001	<	<	--	--	--	--	--
1T2-2	-	-	-	<	--	--	--	--	--
1T2-3	-	-	-	<	--	--	--	--	--
1T2-4	-	-	-	<	--	--	--	--	--
1T2-5	-	-	-	-	0.198	0.053	0.016	0.070[c]	0.119[c]
1T2-6	-	-	-	-	0.024	0.007	0.002	0.010[c]	0.013[c]
1T2-7	-	-	-	-	0.005	<	<	0.002[c]	0.003[c]
1T2-8	-	-	-	-	0.002	<	<	0.001[c]	0.001[c]
1T2-9	-	-	-	-	<0.001	<	<	<0.001[c]	<[b]
1D1-1	-	-	-	2.5	2.0	9.2	0.74	1.35[d]	2.5[d]
1T4-1	-	<0.001	<	--	--	--	--	--	--
1T4-3	-	-	<	--	--	--	--	--	--
1T4-4	-	-	<	--	--	--	--	--	--
1T4-5	-	-	-	<	0.094	0.066	0.004	0.155[c]	0.182[b]
1T4-6	-	-	-	<	0.014	0.014	0.003	0.037[c]	0.045[b]
1T4-7	-	-	-	<	0.004	0.002	<0.001	0.007[c]	0.008[b]
1T4-8	-	-	-	<	<0.001	<0.001	<	0.002[c]	0.002[b]
1T4-9	-	-	-	<	<	<	<	<0.001[c]	<[b]
1T4-10	-	-	-	-	0.062	0.041	0.009	0.078[c]	0.103[c]
1T4-11	-	-	-	-	0.014	0.006	0.002	0.020[c]	0.018[c]
1T4-12	-	-	-	-	0.004	0.003	<	0.005[c]	0.006[c]
1T4-13	-	-	-	-	0.002	0.002	<	0.003[c]	0.003[c]
1T4-14	-	-	-	-	0.001	0.001	<	0.001[c]	0.002[c]

a = not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 A current.

\- = measurement point not established.
-- = measurement point dropped.
/ = measurement not taken.
\# = measurement precluded by antenna operation.
< = measurement est. <0.001 V/m based on earth E-field.

TABLE A-3. 60 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Small Mammals and Nesting Birds Studies
(page 4 of 4)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991
1D2-1	-	-	-	<	<	<	0.004	0.005[d]	0.007[d]
1T5-1	-	<0.001	<	<	0.118	0.157	#	0.29[c]	0.20[b]
1T5-7	-	-	-	-	0.019	0.019	#	0.067[c]	0.042[b]
1T5-8	-	-	-	-	<0.001	<	#	<0.001[c]	/
1T5-4	-	-	-	<	<	<	#	<0.001[c]	/
1T5-2	<0.001	<0.001	<	<	0.074	0.130	#	0.043[b]	0.20[b]
1T5-9	-	-	-	-	0.014	0.017	#	0.006[b]	0.025[b]
1T5-10	-	-	-	-	0.002	0.004	#	0.001[b]	0.007[b]
1T5-6	-	-	-	<	<0.001	<	#	<0.001[b]	0.002[b]
1T5-3	-	-	-	<	--	--	--	--	--
1T5-5	-	-	-	<	<0.001	0.001	#	<0.001[b]	0.002[b]
1T6-2	-	-	-	-	0.162	0.46	#	0.141/0.30[b/c]	/
1T6-1	<0.001	<0.001,0.001	<	<	0.024	0.079	#	0.024/0.048[b/c]	/
1T6-3	-	-	-	-	0.003	0.003	#	<0.001[b/c]	/
1T6-4	-	-	-	-	0.001	0.003	#	<[b/c]	/
1T6-5	-	-	-	-	0.001	0.002	#	<[b/c]	/
1T6-6	-	-	-	-	0.001	<0.001	#	<[b]	/
1T6-7	-	-	-	-	<0.001	<0.001	#	<[b]	/

a = not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 A current.

- = measurement point not established.
-- = measurement point dropped.
/ = measurement not taken.
= measurement precluded by antenna operation.
< = measurement est. <0.001 V/m based on earth E-field.

TABLE A-4. 60 Hz EARTH ELECTRIC FIELD INTENSITES (mV/m)
Small Mammals and Nesting Birds Studies
(page 1 of 4)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991
1C1-2	0.041	0.146	0.056	--	--	--	--	--	--
1C1-3	-	-	0.128	0.082	0.114	0.59	0.053	0.046[d]	0.085[d]
1C1-4	-	-	-	0.117	0.114	0.085	0.22	0.066[d]	0.079[d]
1C3-1	0.106	0.26	0.133	0.086	0.118	0.085	0.135	0.056[d]	0.078[d]
1C3-2	0.125	0.191	/	--	--	--	--	--	--
1C3-3	-	-	-	0.074	0.178	0.148	0.22	0.163[d]	0.125[d]
1C4-1	-	0.028,0.030	0.045	0.065	0.093	0.087	0.041	0.032[d]	0.061[d]
1C4-2	-	0.019,0.023	0.015	--	--	--	--	--	--
1C4-3	-	0.036,0.065	0.103	0.118	--	--	--	--	--
1C4-4	-	-	0.009,0.017	0.011	0.011	0.011	0.010	0.016[d]	0.012[d]
1C4-5	-	-	-	-	0.037	0.046	0.021	0.018[d]	0.036[d]
1D3-1	-	-	-	0.052	0.156	0.053	0.29	0.26[d]	0.103[d]
1C6-1	-	0.072	0.095	0.088	0.106	0.057	0.102	0.103[d]	0.101[d]
1C6-3	-	-	0.123	0.109	0.141	0.053	0.122	0.075[d]	0.069[d]
1C6-4	-	-	0.038	0.007	0.020	0.013	0.013	0.021[d]	0.017[d]
1L4-1	-		-	-	-	0.019	0.013	0.022[d]	0.015[d]

a = not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 A current.

- = measurement point not established.
-- = measurement point dropped.
/ = measurement not taken.
= measurement precluded by antenna operation.

TABLE A-4. 60 Hz EARTH ELECTRIC FIELD INTENSITES (mV/m)
Small Mammals and Nesting Birds Studies
(page 2 of 4)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991
1T1-1	0.090	0.091	0.131	--	--	--	--	--	--
1T1-3	-	0.21	0.179	--	--	--	--	--	-
1T1-4	-	0.174	0.171	--	--	--	--	--	--
1T1-10	-	0.097	0.147	--	--	--	--	--	--
1T1-12	-	-	0.033	--	--	--	--	--	--
1T1-13	-	-	0.034	--	--	--	--	--	--
1T1-14	-	-	-	0.102	0.058	0.29	0.071	0.071[b]	0.036[c]
1T1-15	-	-	-	0.040	0.029	0.064	#	0.025[b]	0.016[c]
1T1-16	-	-	-	0.115	0.102	0.40	#	0.179[b]	0.045[c]
1T1-17	-	-	-	0.118	0.128	0.37	#	0.102[b]	0.053[b]
1T1-18	-	-	-	0.100	0.104	0.46	#	0.081[b]	0.048[b]
1T1-19	-	-	-	0.112	0.132	0.43	#	0.101[b]	0.070[b]
1T1-20	-	-	-	0.118	0.123	0.43	#	0.099[b]	0.065[b]
1T1-28	-	-	-	-	-	0.018	#	0.100[b]	0.073[b]
1T1-29	-	-	-	-	-	0.014	#	0.078[b]	0.046[b]
1T1-30	-	-	-	-	-	0.019	#	0.066[b]	0.047[b]
1T1-31	-	-	-	-	-	0.022	#	0.068[b]	0.048[b]
1T1-21	-	-	-	0.082	0.082	0.53	0.113	0.060[b]	0.137[b]
1T1-22	-	-	-	0.050	0.047	0.40	0.086	0.049[b]	0.090[b]
1T1-23	-	-	-	0.037	0.037	0.31	0.068	0.024[b]	0.090[b]
1T1-24	-	-	-	0.042	0.058	0.23	0.126	0.040[b]	0.070[b]
1T1-25	-	-	-	0.033	0.035	0.26	0.070	0.034[b]	0.075[b]
1T1-26	-	-	-	0.022	0.025	0.20	0.052	0.023[b]	0.045[b]
1T1-27	-	-	-	0.014	0.021	0.094	0.056	0.015[b]	0.032[b]

a = not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 A current.

- = measurement point not established.
-- = measurement point dropped.
/ = measurement not taken.
= measurement precluded by antenna operation.

TABLE A-4. 60 Hz EARTH ELECTRIC FIELD INTENSITES (mV/m)
Small Mammals and Nesting Birds Studies
(page 3 of 4)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991
1T2-1	0.170	0.22	0.197	0.122	--	--	--	--	--
1T2-2	-	-	-	0.047	--	--	--	--	--
1T2-3	-	-	-	0.083	--	--	--	--	--
1T2-4	-	-	-	0.044	--	--	--	--	--
1T2-5	-	-	-	-	0.074	0.074	0.047	0.055[c]	0.078[b]
1T2-6	-	-	-	-	0.069	0.087	0.064	0.064[c]	0.065[b]
1T2-7	-	-	-	-	0.047	0.062	0.040	0.044[c]	0.049[b]
1T2-8	-	-	-	-	0.051	0.067	0.055	0.047[c]	0.047[b]
1T2-9	-	-	-	-	0.055	0.087	0.031	0.044[c]	0.048[b]
1D1-1	-	-	-	9.6	2.4	1.15	2.7	1.96[d]	2.5[d]
1T4-1	-	0.178,0.184	0.150	--	--	--	--	--	--
1T4-3	-	-	0.22	--	--	--	--	--	--
1T4-4	-	-	0.131	--	--	--	--	--	--
1T4-5	-	-	-	0.052	0.081	0.135	0.035	0.147[c]	0.160[b]
1T4-6	-	-	-	0.104	0.066	0.128	0.039	0.106[c]	0.163[b]
1T4-7	-	-	-	0.102	0.090	0.128	0.036	0.126[c]	0.121[b]
1T4-8	-	-	-	0.082	0.078	0.096	0.032	0.186[c]	0.113[b]
1T4-9	-	-	-	0.088	0.063	0.098	0.032	0.200[c]	0.139[b]
1T4-10	-	-	-	-	0.135	0.124	0.126	0.22[c]	0.090[c]
1T4-11	-	-	-	-	0.071	0.089	0.047	0.191[c]	0.116[c]
1T4-12	-	-	-	-	0.071	0.100	0.041	0.181[c]	0.068[c]
1T4-13	-	-	-	-	0.063	0.083	0.037	0.161[c]	0.064[c]
1T4-14	-	-	-	-	0.068	0.121	0.037	0.148[c]	0.064[c]

a = not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 A current.

- = measurement point not established.
-- = measurement point dropped.
/ = measurement not taken.
= measurement precluded by antenna operation.

TABLE A-4. 60 Hz EARTH ELECTRIC FIELD INTENSITES (mV/m)
Small Mammals and Nesting Birds Studies
(page 4 of 4)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991
1D2-1	-	-	-	0.47	0.160	0.28	0.69	0.59[d]	0.58[d]
1T5-1	-	0.24,0.42	0.25	0.115	0.128	0.34	#	0.41[c]	0.21[b]
1T5-7	-	-	-	-	0.107	0.33	#	0.37[c]	0.154[b]
1T5-8	-	-	-	-	0.099	0.23	#	0.37[c]	0.138[b]
1T5-4	-	-	-	0.061	0.073	0.166	#	0.26[c]	0.106[b]
1T5-2	0.23	0.26	0.22	0.042	0.092	0.108	#	0.062[b]	0.135[b]
1T5-9	-	-	-	-	0.080	0.089	#	0.054[b]	0.100[b]
1T5-10	-	-	-	-	0.036	0.056	#	0.030[b]	0.055[b]
1T5-6	-	-	-	0.051	0.034	0.053	#	0.024[b]	0.064[b]
1T5-3	-	-	-	0.125	--	--	--	--	--
1T5-5	-	-	-	0.077	0.051	0.059	#	0.052[b]	0.26[c]
1T6-2	-	-	-	-	0.48	1.52	#	0.29,0.70[b,c]	0.31,0.23[b,c]
1T6-1	0.071	0.65,0.88	0.86,0.88	0.23	0.54	1.49	#	0.39,0.90[b,c]	0.149,0.131[b,c]
1T6-3	-	-	-	-	0.32	1.54	#	0.31,0.83[b,c]	0.29,0.148[b,c]
1T6-4	-	-	-	-	0.25	1.32	#	0.25,0.44[b,c]	0.181,0.167[b,c]
1T6-5	-	-	-	-	0.21	1.19	#	0.21,0.63[b,c]	0.29[c]
1T6-6	-	-	-	-	0.178	0.90	#	0.169[b]	0.33[c]
1T6-7	-	-	-	-	0.100	1.31	#	0.20[b]	0.76[b]

a = not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 A current.

\- = measurement point not established.
-- = measurement point dropped.
/ = measurement not taken.
\# = measurement precluded by antenna operation.

TABLE A-5. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Small Mammals and Nesting Birds Studies
(page 1 of 4)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991
1C1-2	<0.001	0.001	0.001	--	--	--	--	--	--
1C1-3	-	-	0.001	0.001	0.001	0.001	0.001	0.001[d]	0.001[d]
1C1-4	-	-	-	0.001	0.001	0.001	0.001	0.001[d]	0.001[d]
1C3-1	<0.001	0.002	0.002	0.001	0.001	0.001	0.001	0.001[d]	0.001[d]
1C3-2	0.001	0.003	/	--	--	--	--	--	--
1C3-3	-	-	-	0.001	0.001	0.001	0.001	0.001[d]	0.001[d]
1C4-1	-	<0.001,0.001	0.001	0.001	0.002	0.001	0.001	0.001[d]	0.001[d]
1C4-2	-	0.002	0.002	--	--	--	--	--	--
1C4-3	-	<0.001,0.002	<0.001	0.001	--	--	--	--	--
1C4-4	-	-	0.003	0.002	0.002	0.001	0.001	0.002[d]	0.002[d]
1C4-5	-	-	-	-	0.001	0.002	0.001	0.002[d]	0.001[d]
1D3-1	-	-	-	0.003	0.002	0.002	0.013	0.009[d]	0.009[d]
1C6-1	-	0.003	0.003	0.002	<0.001	0.002	0.003	0.002[d]	0.002[d]
1C6-3	-	-	0.003	0.003	0.003	0.002	0.002	0.003[d]	0.002[d]
1C6-4	-	-	0.003	0.003	0.004	0.003	0.003	0.004[d]	0.003[d]
1L4-1	-	-	-	-	-	0.003	0.002	0.002[d]	0.002[d]

a = not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 A current.

\- = measurement point not established.
-- = measurement point dropped.
/ = measurement not taken.
\# = measurement precluded by antenna operation.

TABLE A-5. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Small Mammals and Nesting Birds Studies
(page 2 of 4)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991
1T1-1	0.002	0.002	0.002	--	--	--	--	--	--
1T1-3	-	0.002	0.002	--	--	--	--	--	--
1T1-4	-	0.002	0.002	--	--	--	--	--	--
1T1-10	-	0.004	0.003	--	--	--	--	--	--
1T1-12	-	-	0.004	--	--	--	--	--	--
1T1-13	-	-	0.005	--	--	--	--	--	--
1T1-14	-	-	-	0.004	0.003	0.014	0.003	0.002[b]	0.003[c]
1T1-15	-	-	-	0.004	0.004	0.009	#	0.003[b]	0.001[c]
1T1-16	-	-	-	0.009	0.006	0.22	#	0.009[b]	0.002[c]
1T1-17	-	-	-	0.007	0.009	0.031	#	0.007[b]	0.008[b]
1T1-18	-	-	-	0.006	0.008	0.028	#	0.006[b]	0.007[b]
1T1-19	-	-	-	0.001	0.009	0.032	#	0.007[b]	0.007[b]
1T1-20	-	-	-	0.008	0.011	0.034	#	0.008[b]	0.008[b]
1T1-28	-	-	-	-	-	0.001	#	0.006[b]	0.007[b]
1T1-29	-	-	-	-	-	0.001	#	0.006[b]	0.006[b]
1T1-30	-	-	-	-	-	0.001	#	0.006[b]	0.007[b]
1T1-31	-	-	-	-	-	0.001	#	0.006[b]	0.005[b]
1T1-21	-	-	-	0.055	0.042	0.29	0.072	0.036[b]	0.081[b]
1T1-22	-	-	-	0.012	0.018	0.108	0.029	0.014[b]	0.032[b]
1T1-23	-	-	-	0.008	0.011	0.060	0.015	0.006[b]	0.017[b]
1T1-24	-	-	-	0.005	0.008	0.041	0.008	0.006[b]	0.013[b]
1T1-25	-	-	-	0.005	0.005	0.030	0.007	0.004[b]	0.009[b]
1T1-26	-	-	-	0.003	0.004	0.021	0.005	0.003[b]	0.006[b]
1T1-27	-	-	-	0.002	0.003	0.014	0.004	0.002[b]	0.005[b]

a = not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 A current.

- = measurement point not established.
-- = measurement point dropped.
/ = measurement not taken.
= measurement precluded by antenna operation.

TABLE A-5. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Small Mammals and Nesting Birds Studies
(page 3 of 4)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991
1T2-1	<0.001	0.001	0.001	0.077	--	--	--	--	--
1T2-2	-	-	-	0.009	--	--	--	--	--
1T2-3	-	-	-	0.006	--	--	--	--	--
1T2-4	-	-	-	0.006	--	--	--	--	--
1T2-5	-	-	-	-	0.050	0.023	0.017	0.051[c]	0.054[b]
1T2-6	-	-	-	-	0.018	0.011	0.006	0.019[c]	0.020[b]
1T2-7	-	-	-	-	0.009	0.007	0.003	0.010[c]	0.010[b]
1T2-8	-	-	-	-	0.006	0.005	0.002	0.007[c]	0.006[b]
1T2-9	-	-	-	-	0.005	0.006	0.002	0.005[c]	0.005[b]
1D1-1	-	-	-	0.109	0.154	0.040	0.151	0.141[d]	0.25[d]
1T4-1	-	0.001	0.001	--	--	--	--	--	--
1T4-3	-	-	0.001	--	--	--	--	--	--
1T4-4	-	-	0.001	--	--	--	--	--	--
1T4-5	-	-	-	0.021	0.060	0.061	0.010	0.090[c]	0.104[b]
1T4-6	-	-	-	0.019	0.024	0.017	0.004	0.038[c]	0.046[b]
1T4-7	-	-	-	0.011	0.013	0.010	0.003	0.020[c]	0.023[b]
1T4-8	-	-	-	0.006	0.008	0.005	0.001	0.014[c]	0.015[b]
1T4-9	-	-	-	0.004	0.006	0.004	0.001	0.009[c]	0.012[b]
1T4-10	-	-	-	-	0.051	0.041	0.039	0.081[c]	0.060[c]
1T4-11	-	-	-	-	0.023	0.013	0.004	0.035[c]	0.026[c]
1T4-12	-	-	-	-	0.013	0.010	0.002	0.019[c]	0.013[c]
1T4-13	-	-	-	-	0.009	0.007	0.001	0.013[c]	0.009[c]
1T4-14	-	-	-	-	0.007	0.007	0.001	0.009[c]	0.006[c]

a = not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 A current.

\- = measurement point not established.
-- = measurement point dropped.
/ = measurement not taken.
\# = measurement precluded by antenna operation.

TABLE A-5. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Small Mammals and Nesting Birds Studies
(page 4 of 4)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991
1D2-1	-	-	-	0.004	0.006	0.005	0.005	0.005[d]	0.009[d]
1T5-1	-	0.001,0.002	0.001	0.051	0.071	0.159	#	0.156[c]	0.113[b]
1T5-7	-	-	-	-	0.039	0.077	#	0.087[c]	0.058[b]
1T5-8	-	-	-	-	0.016	0.025	#	0.035[c]	0.024[b]
1T5-4	-	-	-	0.006	0.008	0.016	#	0.020[c]	0.014[b]
1T5-2	0.001	0.002	0.001	0.038	0.042	0.075	#	0.020[b]	0.112[b]
1T5-9	-	-	-	-	0.019	0.028	#	0.010[b]	0.032[b]
1T5-10	-	-	-	-	0.011	0.017	#	0.005[b]	0.023[b]
1T5-6	-	-	-	0.004	0.008	0.012	#	0.004[b]	0.018[b]
1T5-3	-	-	-	0.007	--	--	--	--	--
1T5-5	-	-	-	0.005	0.019	0.018	#	0.004[b]	0.042[c]
1T6-2	-	-	-	-	0.111	0.34	#	0.087,0.177[b,c]	0.103,0.043[b,c]
1T6-1	0.002	0.001	0.001	0.020	0.058	0.134	#	0.033,0.070[b,c]	0.041,0.020[b,c]
1T6-3	-	-	-	-	0.020	0.061	#	0.014,0.031[b,c]	0.019,0.009[b,c]
1T6-4	-	-	-	-	0.014	0.044	#	0.011,0.021[b,c]	0.012,0.006[b,c]
1T6-5	-	-	-	-	0.011	0.033	#	0.008,0.013[b,c]	0.011[c]
1T6-6	-	-	-	-	0.008	0.023	#	0.005[b]	0.008[c]
1T6-7	-	-	-	-	0.008	0.022	#	0.004[b]	0.006,0.007[b,c]

a = not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 A current.

\- = measurement point not established.
-- = measurement point dropped.
/ = measurement not taken.
= measurement precluded by antenna operation.

TABLE A-6. 76 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Small Mammals and Nesting Birds Studies
(page 1 of 3)

Site No., Meas. Pt.	1986 NS 4 A	1986 NEW 6 A	1986 SEW 6 A	1986 SEW 10 A, EX	1987 NS 15 A	1987 EW 15 A	1988 NS 75 A	1988 EW 75 A	1989 B 150 A	1990 B 150 A	1991 B 150 A
1C1-3	<	<	<	*	<	<	<	<	<	<	<
1C1-4	<	<	<	*	<	<	<	<	<	<	<
1C3-1	<	<	<	*	<	<	<	<	<	<	<
1C3-3	<	<	<	*	<	<	<	<	<	<	<
1C4-1	<	<	<	*	<	<	<	<	<	<	<
1C4-4	<	<	<	*	<	<	<	<	<	<	<
1C4-5	-	-	-	-	<	<	<	<	<	<	<
1D3-1	<	<	<	*	<	<	<	<	<	<	<
1C6-1	<	<	<	*	<	<	<	<	<	<	<
1C6-3	<	<	<	*	<	<	<	<	<	<	<
1C6-4	<	<	<	*	<	<	<	<	<	<	<
1L4-1	-	-	-	-	-	-	<	<	<	<	<
1T1-14	<	<	<	*	0.004	<	0.017	<	0.036	0.036	0.033
1T1-15	<	<	<	*	0.001	<	0.007	<	0.015	0.021	0.015
1T1-16	<	<	<	*	0.004	<	0.012	<	0.043	0.037	0.034
1T1-17	0.002	<	<	*	0.004	<	0.023	<	0.043	0.057	0.045
1T1-18	0.001	<	<	*	0.004	<	0.023	<	0.052	0.055	0.056
1T1-19	0.002	<	<	*	0.005	<	0.032	<	0.055	0.059	0.072
1T1-20	0.002	<	<	*	0.004	<	0.025	<	0.057	0.058	0.046

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.
A = amperes.

- = measurement point not established.
< = measurement est. <0.001 V/m based on earth E-field.
* = data cannot be extrapolated.

TABLE A-6. 76 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Small Mammals and Nesting Birds Studies
(page 2 of 3)

Site No., Meas. Pt.	1986 NS 4 A	1986 NEW 6 A	1986 SEW 6 A	1986 SEW 10 A, EX	1987 NS 15 A	1987 EW 15 A	1988 NS 75 A	1988 EW 75 A	1989 B 150 A	1990 B 150 A	1991 B 150 A
1T1-28	-	-	-	-	-	-	0.016	<	0.043	0.044	0.051
1T1-29	-	-	-	-	-	-	0.013	<	0.032	0.036	0.036
1T1-30	-	-	-	-	-	-	0.017	<	0.037	0.042	0.036
1T1-31	-	-	-	-	-	-	0.016	<	0.035	0.035	0.046
1T1-21	1.08	<	<	*	3.6	0.005	15.7	0.054	32	35	35
1T1-22	0.002	<	<	*	0.005	<0.001	0.024	<	0.049	0.049	0.048
1T1-23	<	<	<	*	0.008	<	0.033	<	0.053	0.073	0.067
1T1-24	<	<	<	*	0.013	<	0.045	<	0.150	0.091	0.129
1T1-25	<	<	<	*	0.019	<	0.059	<	0.160	0.135	0.126
1T1-26	<	<	<	*	0.012	<	0.044	<	0.092	0.102	0.099
1T1-27	<	<	<	*	0.008	<	0.032	<	0.060	0.068	0.065
1T2-5	-	-	-	-	1.28	0.014	7.3	0.100	11.1	12.2	10.7
1T2-6	-	-	-	-	0.169	0.002	0.84	0.013	1.17	1.33	1.29
1T2-7	-	-	-	-	0.034	<0.001	0.29	0.004	0.25	0.34	0.27
1T2-8	-	-	-	-	0.014	<	0.084	0.004	0.104	0.142	0.109
1T2-9	-	-	-	-	0.008	<	0.035	0.004	0.077	0.082	0.066
1D1-1	<	<	<	*	<	<	<	<	0.007	0.010	0.009
1T4-5	0.58	<	<	*	2.1	0.003	8.7	0.044	17.6	18.4	21
1T4-6	0.091	<	<	*	0.31	<0.001	1.76	0.009	4.2	4.6	4.0
1T4-7	0.022	<	<	*	0.089	<	0.35	0.003	0.69	0.86	0.76
1T4-8	0.005	<	<	*	0.014	<	0.054	0.002	0.093	0.091	0.112
1T4-9	0.002	<	<	*	0.008	<	0.045	0.002	0.081	0.081	0.106

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, *standard* phasing.
EX = extrapolated data.
A = amperes.

- = measurement point not established.
< = measurement est. <0.001 V/m based on earth E-field.
* = data cannot be extrapolated.

TABLE A-6. 76 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Small Mammals and Nesting Birds Studies
(page 3 of 3)

Site No., Meas. Pt.	1986 NS 4 A	1986 NEW 6 A	1986 SEW 6 A	1986 SEW 10 A, EX	1987 NS 15 A	1987 EW 15 A	1988 NS 75 A	1988 EW 75 A	1989 B 150 A	1990 B 150 A	1991 B 150 A
1T4-10	-	-	-	-	1.30	0.001	6.4	0.033	12.3	15.1	17.4
1T4-11	-	-	-	-	0.30	<0.001	1.48	0.008	2.4	3.1	4.7
1T4-12	-	-	-	-	0.090	<0.001	0.39	0.003	0.69	1.02	0.90
1T4-13	-	-	-	-	0.033	<0.001	0.115	0.002	0.33	0.36	0.37
1T4-14	-	-	-	-	0.015	<0.001	0.066	0.002	0.128	0.120	0.133
1D2-1	<	<	<	*	<	0.003	0.001	0.001	0.011	0.013	0.019
1T5-1	0.81	<	<	*	3.1	0.005	12.4	0.040	26	41	33
1T5-7	-	-	-	-	0.54	0.001	1.78	0.005	5.2	7.6	5.8
1T5-8	-	-	-	-	0.008	<0.001	0.039	<	0.079	0.113	0.096
1T5-4	0.002	<	<	*	0.007	<	0.039	<	0.066	0.089	0.086
1T5-2	0.59	<	<	*	2.9	0.003	15.8	0.056	23	42	28
1T5-9	-	-	-	-	0.44	<0.001	1.95	0.007	3.4	6.3	3.6
1T5-10	-	-	-	-	0.076	<	0.29	0.001	0.63	1.06	0.86
1T5-6	0.009	<	<	*	0.022	<	0.135	<	0.23	0.46	0.31
1T5-5	0.005	<	<	*	0.019	<	0.095	0.001	0.178	0.40	0.23
1T6-2	-	-	-	-	3.2	0.005	14.3	0.054	31	42	43
1T6-1	0.182	<	<	*	0.48	<	2.4	0.010	4.9	6.2	6.7
1T6-3	-	-	-	-	0.042	<0.001	0.121	<0.001	0.35	0.54	0.47
1T6-4	-	-	-	-	0.029	<0.001	0.122	<0.001	0.23	0.24	0.28
1T6-5	-	-	-	-	0.021	<0.001	0.107	<0.001	0.153	0.164	0.172
1T6-6	-	-	-	-	0.019	<0.001	0.075	<0.001	0.151	0.185	0.137
1T6-7	-	-	-	-	0.015	<0.001	0.079	0.001	0.142	0.159	0.145

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.
A = amperes.

\- = measurement point not established.
< = measurement est. <0.001 V/m based on earth E-field.
* = data cannot be extrapolated.

TABLE A-7. 76 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Small Mammals and Nesting Birds Studies
(page 1 of 3)

Site No., Meas. Pt.	1986				1987		1988		1989	1990	1991
	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	B 150 A
1C1-3	0.021	0.003	0.010	0.017	0.082	0.028	0.44	0.139	1.31	1.04	1.20
1C1-4	/	/	/	/	0.087	0.033	0.42	0.185	1.70	1.33	1.23
1C3-1	/	/	/	/	0.050	0.025	0.26	0.119	0.74	0.81	0.95
1C3-3	0.022	0.004	0.012	0.020	0.086	0.032	0.41	0.157	1.18	0.98	0.94
1C4-1	/	/	/	/	0.005	0.004	0.023	0.019	0.070	0.073	0.065
1C4-4	<0.001	<0.001	<0.001	*	0.002	0.002	0.005	0.005	0.030	0.023	0.030
1C4-5	-	-	-	-	0.003	0.002	0.012	0.008	0.037	0.035	0.044
1D3-1	0.008	0.004	0.005	0.008	0.053	0.019	0.21	0.065	0.85	0.89	0.63
1C6-1	/	/	/	/	0.004	0.003	0.017	0.017	0.083	0.100	0.069
1C6-3	0.001	<0.001	0.001	0.002	0.008	0.004	0.026	0.016	0.110	0.078	0.075
1C6-4	/	/	/	/	0.003	0.002	0.017	0.009	0.045	0.043	0.043
1L4-1	-	-	-	-	-	-	0.006	0.002	0.013	0.020	0.010
1T1-14	0.86	0.026	0.021	0.035	3.1	0.069	18.1	0.21	34	40	39
1T1-15	0.43	0.013	0.015	0.025	1.60	0.051	9.2	0.21	13.6	14.1	23
1T1-16	1.11	0.035	0.035	0.058	4.6	0.133	24	0.61	47	50	46
1T1-17	1.55	0.049	0.053	0.088	6.2	0.139	23	0.57	43	39	55
1T1-18	1.44	0.042	0.050	0.083	5.6	0.166	26	0.71	49	55	51
1T1-19	1.54	0.050	0.053	0.088	6.4	0.142	28	0.69	57	58	60
1T1-20	1.45	0.046	0.043	0.072	6.0	0.142	28	0.77	56	56	53

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.
A = amperes.

- = measurement point not established.
/ = measurement not taken.
* = data cannot be extrapolated.

TABLE A-7. 76 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Small Mammals and Nesting Birds Studies
(page 2 of 3)

Site No., Meas. Pt.	1986				1987		1988		1989	1990	1991
	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	B 150 A
1T1-28	-	-	-	-	-	-	25	0.74	54	58	55
1T1-29	-	-	-	-	-	-	16.1	0.58	35	37	38
1T1-30	-	-	-	-	-	-	17.2	0.63	39	41	35
1T1-31	-	-	-	-	-	-	20	0.71	41	40	44
1T1-21	1.45	0.044	0.009	0.015	7.4	0.026	31	0.133	54	49	60
1T1-22	1.50	0.042	0.009	0.015	4.2	0.021	25	0.62	41	42	43
1T1-23	0.96	0.030	0.003	0.005	2.9	0.017	18.7	0.109	33	30	27
1T1-24	1.15	0.036	0.010	0.017	4.7	0.020	14.8	0.117	59	35	33
1T1-25	0.87	0.027	0.062	0.103	2.9	0.019	15.6	0.079	33	29	21
1T1-26	0.56	0.017	0.004	0.007	2.0	0.014	12.3	0.082	23	23	20
1T1-27	0.38	0.012	0.004	0.007	1.82	0.015	6.2	0.057	19.3	13.7	13.0
1T2-5	-	-	-	-	8.7	0.77	39	3.1	85	88	94
1T2-6	-	-	-	-	8.5	0.86	41	4.6	86	82	81
1T2-7	-	-	-	-	7.0	0.56	31	2.7	70	66	66
1T2-8	-	-	-	-	7.1	0.66	31	3.6	70	67	79
1T2-9	-	-	-	-	6.2	0.79	31	3.6	70	65	69
1D1-1	0.042	0.28	0.066	0.110	0.23	0.67	1.15	3.4	7.6	6.1	5.7
1T4-5	2.1	0.062	0.054	0.090	6.4	0.191	34	0.76	84	68	62
1T4-6	2.5	0.076	0.103	0.172	6.3	0.29	45	1.35	87	64	89
1T4-7	2.2	0.067	0.092	0.153	8.7	0.30	37	1.40	76	50	64
1T4-8	1.91	0.061	0.123	0.21	7.7	0.31	32	1.59	72	70	61
1T4-9	2.1	0.062	0.126	0.21	6.2	0.34	35	1.74	55	82	50

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.
A = amperes.

- = measurement point not established.
/ = measurement not taken.
* = data cannot be extrapolated.

TABLE A-7. 76 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Small Mammals and Nesting Birds Studies
(page 3 of 3)

Site No.,	1986				1987		1988		1989	1990	1991
Meas. Pt.	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	B 150 A
1T4-10	-	-	-	-	12.4	0.29	47	1.30	86	97	84
1T4-11	-	-	-	-	6.4	0.27	34	1.26	83	79	106
1T4-12	-	-	-	-	7.4	0.38	39	1.31	76	75	78
1T4-13	-	-	-	-	5.7	0.33	29	1.60	70	66	73
1T4-14	-	-	-	-	6.7	0.33	31	1.56	55	72	64
1D2-1	0.094	0.44	0.113	0.188	0.41	1.36	1.58	4.8	9.7	10.2	10.2
1T5-1	2.6	0.079	0.074	0.123	9.7	0.21	47	0.94	110	85	107
1T5-7	-	-	-	-	8.4	0.21	48	1.01	78	84	86
1T5-8	-	-	-	-	8.2	0.20	38	0.87	90	92	81
1T5-4	1.39	0.042	0.061	0.102	5.8	0.21	29	0.98	61	69	75
1T5-2	1.97	0.064	0.108	0.180	8.2	0.23	24	0.77	70	54	44
1T5-9	-	-	-	-	7.2	0.29	19.5	0.84	47	54	59
1T5-10	-	-	-	-	3.4	0.170	14.4	1.00	36	32	33
1T5-6	1.08	0.037	0.070	0.117	3.3	0.21	13.1	0.98	32	38	32
1T5-5	1.31	0.051	0.101	0.168	5.2	0.33	23	1.40	45	53	54
1T6-2	-	-	-	-	27.	0.24	71	0.79	250	270	196
1T6-1	5.4	0.159	0.086	0.143	32.	0.25	102	1.03	169	122	98
1T6-3	-	-	-	-	21.	0.144	97	0.67	187	240	188
1T6-4	-	-	-	-	16.3	0.122	87	0.61	139	236	164
1T6-5	-	-	-	-	15.3	0.22	80	1.27	143	124	137
1T6-6	-	-	-	-	11.6	0.132	63	0.66	128	103	119
1T6-7	-	-	-	-	6.0	0.178	87	1.41	120	177	69

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.
A = amperes.

\- = measurement point not established.
/ = measurement not taken.
* = data cannot be extrapolated.

TABLE A-8. 76 Hz MAGNETIC FIELD INTENSITIES (mG)
Small Mammals and Nesting Birds Studies
(page 1 of 3)

	1986				1987		1988		1989	1990	1991
Site No., Meas. Pt.	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	B 150 A
1C1-3	<0.001	<0.001	<0.001	*	0.001	<0.001	0.003	0.001	0.007	0.007	0.007
1C1-4	/	/	/	/	0.001	<0.001	0.003	0.001	0.006	0.006	0.007
1C3-1	/	/	/	/	0.001	<0.001	0.003	0.001	0.008	0.007	0.008
1C3-3	<0.001	<0.001	<0.001	*	0.001	<0.001	0.003	0.001	0.007	0.008	0.007
1C4-1	/	/	/	/	<0.001	<0.001	0.001	<0.001	0.001	0.002	0.001
1C4-4	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.001	<0.001	0.002	0.002	0.002
1C4-5	-	-	-	-	<0.001	<0.001	0.001	<0.001	0.002	0.002	0.002
1D3-1	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.002	0.002	0.008	0.008	0.004
1C6-1	/	/	/	/	<0.001	<0.001	0.001	0.001	0.004	0.003	0.003
1C6-3	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.001	0.001	0.004	0.004	0.003
1C6-4	/	/	/	/	<0.001	<0.001	0.002	0.001	0.005	0.005	0.003
1L4-1	-	-	-	-	-	-	<0.001	<0.001	0.002	0.002	0.002
1T1-14	0.032	0.001	0.001	0.002	0.115	0.003	0.65	0.014	1.35	1.29	1.24
1T1-15	0.027	0.001	0.001	0.002	0.097	0.003	0.47	0.012	1.01	0.98	0.97
1T1-16	0.069	0.002	0.001	0.002	0.22	0.002	1.05	0.013	2.1	2.1	2.0
1T1-17	0.076	0.003	0.001	0.002	0.23	0.001	1.49	0.012	2.9	2.9	2.8
1T1-18	0.071	0.002	0.001	0.002	0.27	0.002	1.28	0.012	2.6	2.6	2.5
1T1-19	0.081	0.003	0.001	0.002	0.32	0.002	1.51	0.013	3.1	3.1	2.9
1T1-20	0.089	0.003	0.001	0.002	0.36	0.002	1.68	0.013	3.3	3.4	3.2

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.
A = amperes.

- = measurement point not established.
/ = measurement not taken.
* = data cannot be extrapolated.

TABLE A-8. 76 Hz MAGNETIC FIELD INTENSITIES (mG)
Small Mammals and Nesting Birds Studies
(page 2 of 3)

Site No.,	1986				1987		1988		1989	1990	1991
Meas. Pt.	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	B 150 A
1T1-28	-	-	-	-	-	-	1.25	0.015	2.4	2.4	2.4
1T1-29	-	-	-	-	-	-	1.10	0.015	2.1	2.2	2.1
1T1-30	-	-	-	-	-	-	1.12	0.015	2.3	2.3	2.1
1T1-31	-	-	-	-	-	-	1.00	0.015	2.1	2.1	1.91
1T1-21	0.78	0.024	0.004	0.007	2.9	0.005	13.8	0.043	32	29	28
1T1-22	0.31	0.010	0.002	0.003	1.16	0.016	5.8	0.019	12.3	11.6	11.0
1T1-23	0.169	0.005	0.001	0.002	0.64	0.003	3.0	0.013	6.6	6.0	5.9
1T1-24	0.113	0.004	0.001	0.002	0.43	0.003	2.1	0.011	4.3	4.2	4.1
1T1-25	0.084	0.003	0.007	0.012	0.32	0.003	1.52	0.011	3.4	3.2	3.0
1T1-26	0.055	0.002	0.001	0.002	0.21	0.002	1.00	0.010	2.2	1.92	1.93
1T1-27	0.040	0.012	0.001	0.002	0.149	0.002	0.69	0.009	1.51	1.39	1.33
1T2-5	-	-	-	-	3.2	0.005	15.1	0.053	33	30	29
1T2-6	-	-	-	-	1.23	0.003	5.8	0.031	12.0	11.1	10.9
1T2-7	-	-	-	-	0.64	0.002	3.1	0.023	6.4	6.2	5.8
1T2-8	-	-	-	-	0.43	0.003	2.1	0.020	4.3	4.0	3.9
1T2-9	-	-	-	-	0.32	0.003	1.59	0.019	3.3	3.0	3.0
1D1-1	<0.001	0.003	0.001	0.002	0.001	0.011	0.004	0.053	0.102	0.131	0.167
1T4-5	0.70	0.022	0.004	0.007	2.9	0.004	13.4	0.047	29	28	26
1T4-6	0.32	0.010	0.002	0.003	1.21	0.002	5.7	0.025	12.6	11.6	11.3
1T4-7	0.171	0.005	0.001	0.002	0.66	0.001	3.1	0.017	6.4	6.0	6.4
1T4-8	0.116	0.003	0.001	0.002	0.43	0.002	2.1	0.014	4.3	4.1	4.0
1T4-9	0.085	0.003	0.001	0.002	0.34	0.002	1.55	0.012	3.2	3.0	3.0

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.
A = amperes.

- = measurement point not established.
/ = measurement not taken.
* = data cannot be extrapolated.

TABLE A-8. 76 Hz MAGNETIC FIELD INTENSITIES (mG)
Small Mammals and Nesting Birds Studies
(page 3 of 3)

Site No.,	1986				1987		1988		1989	1990	1991
Meas. Pt.	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	B 150 A
1T4-10	-	-	-	-	2.7	0.004	16.5	0.042	26	25	25
1T4-11	-	-	-	-	0.87	0.003	5.3	0.015	11.7	11	10.5
1T4-12	-	-	-	-	0.64	0.002	2.9	0.008	6.3	5.9	5.8
1T4-13	-	-	-	-	0.43	0.002	2.0	0.007	4.3	4.0	3.9
1T4-14	-	-	-	-	0.32	0.002	1.55	0.006	3.2	3.0	3.0
1D2-1	<0.001	0.003	0.001	0.002	0.002	0.008	0.009	0.043	0.077	0.078	0.075
1T5-1	0.89	0.029	0.005	0.008	3.6	0.005	17.0	0.059	34	34	32
1T5-7	-	-	-	-	1.93	0.002	8.9	0.035	18.9	17.6	16.7
1T5-8	-	-	-	-	0.75	0.001	3.5	0.017	7.3	7.3	6.8
1T5-4	0.124	0.004	0.001	0.002	0.46	0.001	2.2	0.013	4.5	4.4	4.3
1T5-2	0.77	0.024	0.004	0.007	3.1	0.004	14.4	0.052	31	29	27
1T5-9	-	-	-	-	1.18	0.003	5.6	0.017	11.7	11.2	10.8
1T5-10	-	-	-	-	0.67	0.002	3.2	0.009	6.1	6.1	5.9
1T5-6	0.125	0.004	<0.001	*	0.46	0.002	2.1	0.007	4.5	4.5	4.4
1T5-5	0.131	0.004	0.001	0.002	0.53	0.001	2.5	0.014	5.1	5.2	4.9
1T6-2	-	-	-	-	3.9	0.006	17.8	0.061	35	37	36
1T6-1	0.40	0.013	0.002	0.003	1.51	0.004	7.2	0.021	14.7	14.7	13.5
1T6-3	-	-	-	-	0.65	0.002	3.2	0.008	6.5	6.3	6.1
1T6-4	-	-	-	-	0.44	0.002	2.1	0.006	4.7	4.9	4.4
1T6-5	-	-	-	-	0.34	0.002	1.70	0.004	3.5	3.4	3.4
1T6-6	-	-	-	-	0.24	0.016	1.17	0.004	2.4	2.4	2.4
1T6-7	-	-	-	-	0.22	0.002	1.05	0.005	2.1	2.1	2.1

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.
A = amperes.

- = measurement point not established.
/ = measurement not taken.
* = data cannot be extrapolated.

TABLE A-9. 60 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Small Mammals and Nesting Birds Studies Laboratory

Site No., Meas. Pt.	1986	1987	1988	1989	1990 Before Shielding	1990 After Shielding
1L1-1	/	--	--	--	--	--
1L1-2	0.94	0.96	--	--	--	--
1L1-3	0.79	0.034	/	/	/	0.58
1L1-4	0.042	0.047	0.062	/	/	/
1L1-5	-	-	-	/	/	/
1L1-6	-	-	-	/	/	/
1L1-7	-	-	-	8.1	8.5	1.34
1L1-8	-	-	-	0.88	0.76	0.037
1L1-9	-	-	-	60	18.1	3.9*
1L1-10	-	-	-	-	/	0.010

- = measurement point not established.
-- = measurement point dropped.
/ = data not taken.
* = 4.0 V/m with humidifier on.

TABLE A-10. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Small Mammals and Nesting Birds Studies Laboratory

Site No., Meas. Pt.	1986	1987	1988	1989	1990
1L1-1	9.13	--	--	--	--
1L1-2	0.179	0.156	--	--	--
1L1-3	0.080	0.143	/	/	0.071
1L1-4	0.114	0.118	0.080	0.075	/
1L1-5	-	-	-	14.1[1]	5.2[3]
				21[2]	0.62[4]
					0.077[5]
1L1-6	-	-	-	3.2[1]	2.4[3]
				44[2]	0.195[4]
					0.081[5]
1L1-7	-	-	-	0.65	1.69
1L1-8	-	-	-	1.46	0.88
1L1-9	-	-	-	48	0.86
1L1-10	-	-	-	-	0.75

1 = measurement made in vertical orientation only in an open, unshielded can, submerged to its rim.
2 = measurement made above the bath surface.
3 = measurement made in closed, unshielded, fully submerged can.
4 = measurement made in closed, shielded, fully submerged can.
5 = measurement made in closed, shielded, fully submerged can with motor and pump shielding (final configuration; see Figure A-38).
- = measurement point not established.
-- = measurement point dropped.
/ = data not taken.

APPENDIX B

NATIVE BEES STUDIES

NATIVE BEES STUDIES

These studies incorporate investigations of the nesting and development traits of bees native to the ELF system area in Michigan. The electric and magnetic fields present in the air are considered the most important factors in the orientation and site tenacity of bees during their nesting cycle. The electric and magnetic fields in the earth and near its surface may be of importance in developmental studies. The air electric field and magnetic field in the laboratory where the bee nesting blocks are examined, and in the holding areas used prior to examination, are also of importance.

IITRI field crews made ELF electromagnetic (EM) field measurements at 15 measurement points within two treatment sites, two control sites, and the remote holding facility for the native bees studies in 1991. The measurement regime differed from 1990 in that measurements were not taken at the Crystal Falls laboratory to assess the 60 Hz EM exposures. Documentation of previous measurements and EM field shielding activities at the laboratory is included in this appendix, however, for easy reference. Also, measurements were not taken at the control site measurement point 2C5-2 in 1991 because flooding of a dried lakebed prohibited access to this location. Measurement dates for 1991 and previous years appear in Table B-1.

The positions of the six sites relative to the NRTF-Republic are shown on the composite map in Figure B-1. The site numbers listed on the map are those used by IITRI. Table B-2 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites. Details of measurement locations within sites are given in Figures B-2 through B-8.

TABLE B-1. EM FIELD MEASUREMENT DATES
Native Bees Studies

Year	Measurement Dates		
1983	May 25	Jul 13	
1984	May 16	Aug 13-16, 20, 22	
1985	Jul 15, 22, 23		
1986	Oct 6, 8, 13, 16		
1987	Sep 29, 30	Oct 2	
1988	Sep 19-22, 28		
1989	May 10	Sep 13, 20, 22	
1990	May 9	Sep 24	Oct 2, 5, 8
1991	Sep 24, 26	Oct 1, 4, 16	

TABLE B-2. SITE NUMBER CROSS-REFERENCE
Native Bees Studies

IITRI Site No.	Investigator's Site Name	Location Township	Location Range	Location Section(s)
2T1	Ford 1 (F1)	T43N	R29W	14
2T2	Ford 2 (F2)	T43N	R29W	14
2C4	County Line Road (CL)	T43N	R30W	19
2C5	Camp 5 (C5)	T42N	R31W	13
2L1	Crystal Falls Laboratory Marquette Street	T43N	R32W	29
2L2	Remote Holding Facility	T42N	R32W	9

EM field measurements for 1990 and previous years are found in Tables B-3 through B-8. Tables B-3, B-4, and B-5 present 60 Hz data for the air electric field, earth electric field, and magnetic flux density, respectively. Tables B-6, B-7, and B-8 present 76 Hz data for these three fields along with the corresponding operating currents of the NRTF-Republic for each year.

Considerable year-to-year variability in the 60 Hz EM fields is evident. The primary factors in this variability at treatment sites are changes in power line loading conditions (which are unknown) and differences in the configuration of the antennas at the time of measurement. Notes on the antenna configurations are included in the tables primarily for engineering use. The 60 Hz measurements at treatment sites in 1986-1991 (excluding 1989) were taken while the antennas were off, and are representative of 60 Hz levels present during maintenance periods. In 1989, the antenna status (modulated signal) precluded 60 Hz EM field measurements at the treatment sites. However, measurements were possible at treatment sites for other studies in 1989 during unmodulated operation of the antennas. These measurements indicate that 60 Hz EM fields present during operation of the antennas are comparable to those present when the antennas are off.

Annual variations in the 60 Hz fields measured at the control study sites are also caused by differences in power line loading, but are not dependent on the antennas or their configuration because of the distance of these sites from the antennas. The 60 Hz field values at the control sites are about as variable as those at the treatment sites.

Overall, the 60 Hz EM fields measured at all study sites in 1991 are consistent with previous field values and with the expected differences in power line loads and antenna configuration. Regardless of the field variability associated with the measurement condition, 76 Hz EM fields at treatment sites consistently dominate the 60 Hz EM fields at treatment and control sites, and the ratios of 60 Hz EM fields between matched treatment/control sites continue to meet exposure criteria guidelines established at the beginning of the study.

The 76 Hz EM field measurements in 1991 were made with 150 ampere antenna currents, the predominant operating current of the NRTF-Republic since 4 May 1989. The antenna currents at which measurements were made in each year are given in the column headings of the Tables B-6 through B-8. The annual increases in field magnitudes reflect the level of antenna current at the time of measurement: 4 or 6 amperes in 1986, 15 amperes in 1987, 75 amperes in 1988, and 150 amperes in 1989, 1990, and 1991. The 1991 measurements are consistent with the 1989 and 1990 measurements at the same current, and proportional to the 1986, 1987, and 1988 measurements made at lower currents.

The 60 Hz EM fields measured at the Crystal Falls laboratory in 1989 were significantly higher (up to 1000 times) than the 60 Hz fields measured at any of the study sites. Some of the laboratory 60 Hz air electric field exposures even exceeded the 76 Hz exposures at the treatment sites. These relatively high intensities could mask differences caused by exposures at treatment and control sites. As discussed in a previous report,[11] the duration of exposure of nest boxes at the Crystal Falls laboratory has been minimized by using the remote holding facility, set up by the small mammals and nesting birds studies researchers, for temporary nest storage. In addition, IITRI built wire-mesh Faraday cage shields to reduce the 60 Hz air electric field exposures of the bees while at the Crystal Falls laboratory. These cages were installed prior to 1990 laboratory work.

Air electric field shielding at the Crystal Falls laboratory was also discussed in the above-referenced report.[11] Table B-9 presents 60 Hz air electric field data before and after shielding was implemented in the Crystal Falls laboratory. It can be seen from this table that the shields provided a nominal factor of 100 reduction in the air electric field exposure at the laboratory work areas.

The 60 Hz magnetic flux densities measured at the Crystal Falls laboratory appear in Table B-10. The 1990 magnetic flux density levels are similar to those measured in 1989. They are typically at least a factor of 10 lower than the 76 Hz magnetic flux densities measured at the treatment sites during full-power antenna operation. Shielding of the magnetic fields is not being considered for this laboratory.

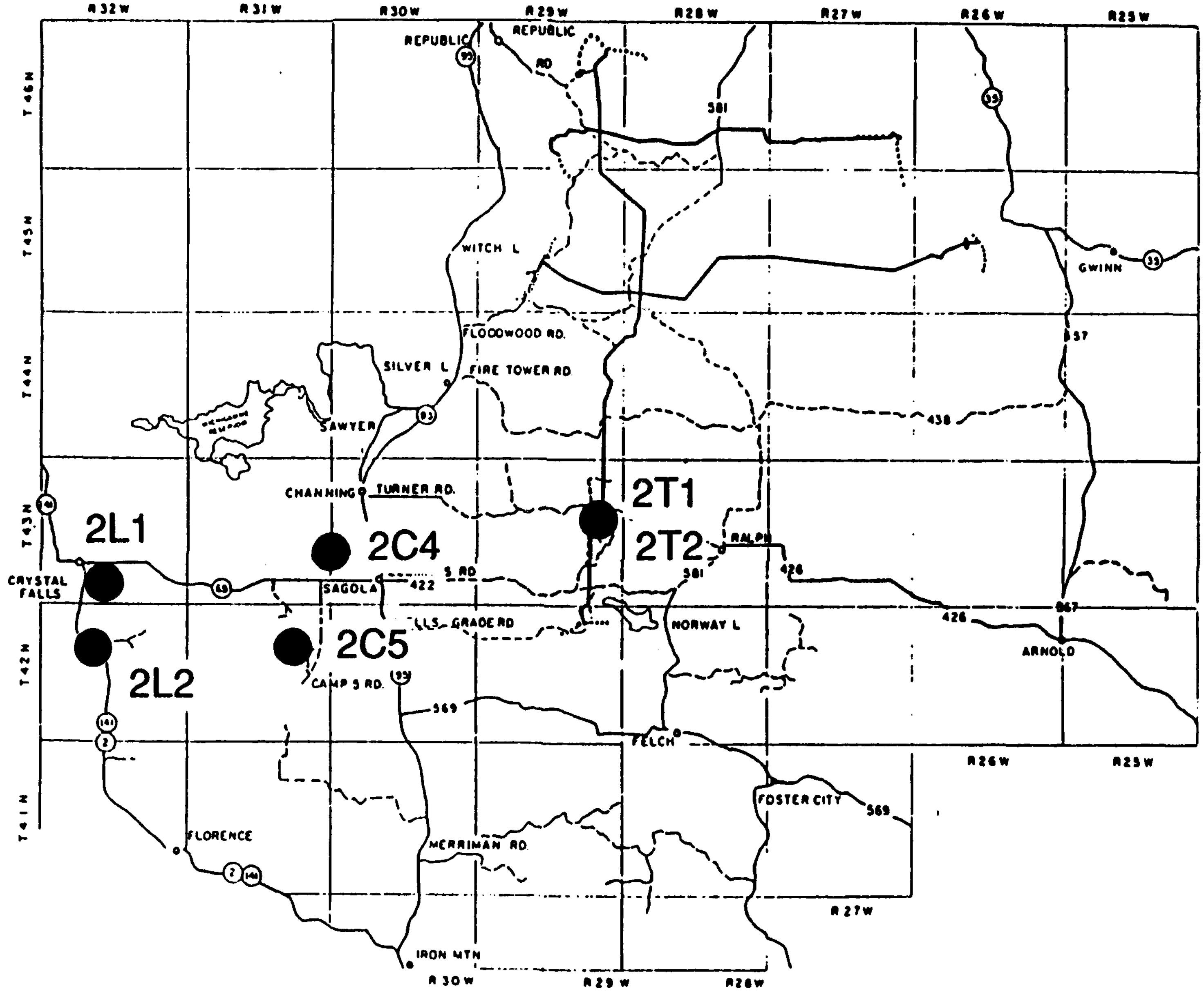


FIGURE B-1. POSITIONS OF NATIVE BEES STUDY SITES RELATIVE TO NRTF-REPUBLIC ANTENNA ELEMENTS.

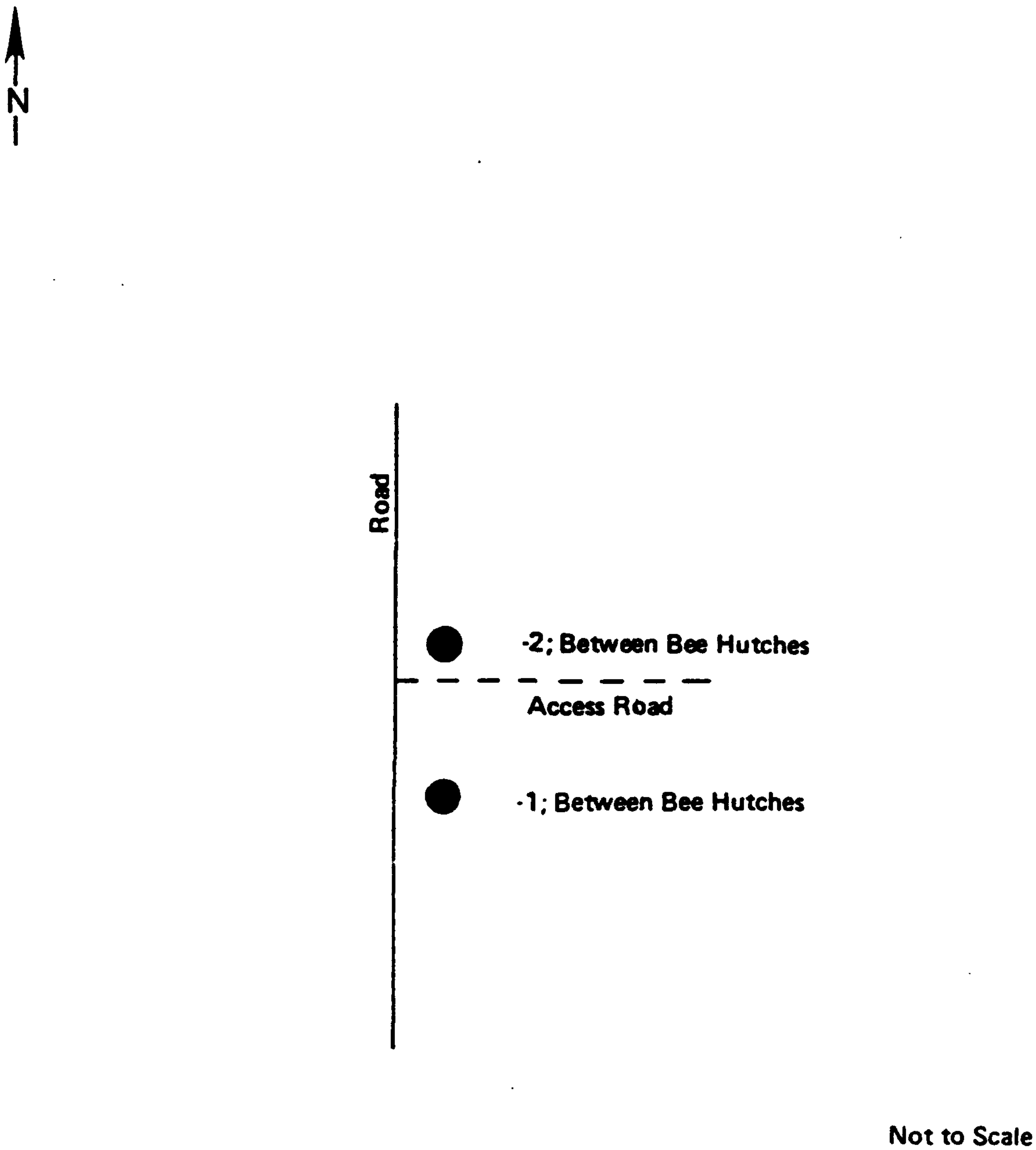


FIGURE B-2. MEASUREMENT POINTS AT COUNTY LINE ROAD (CL); 2C4-1, 2.

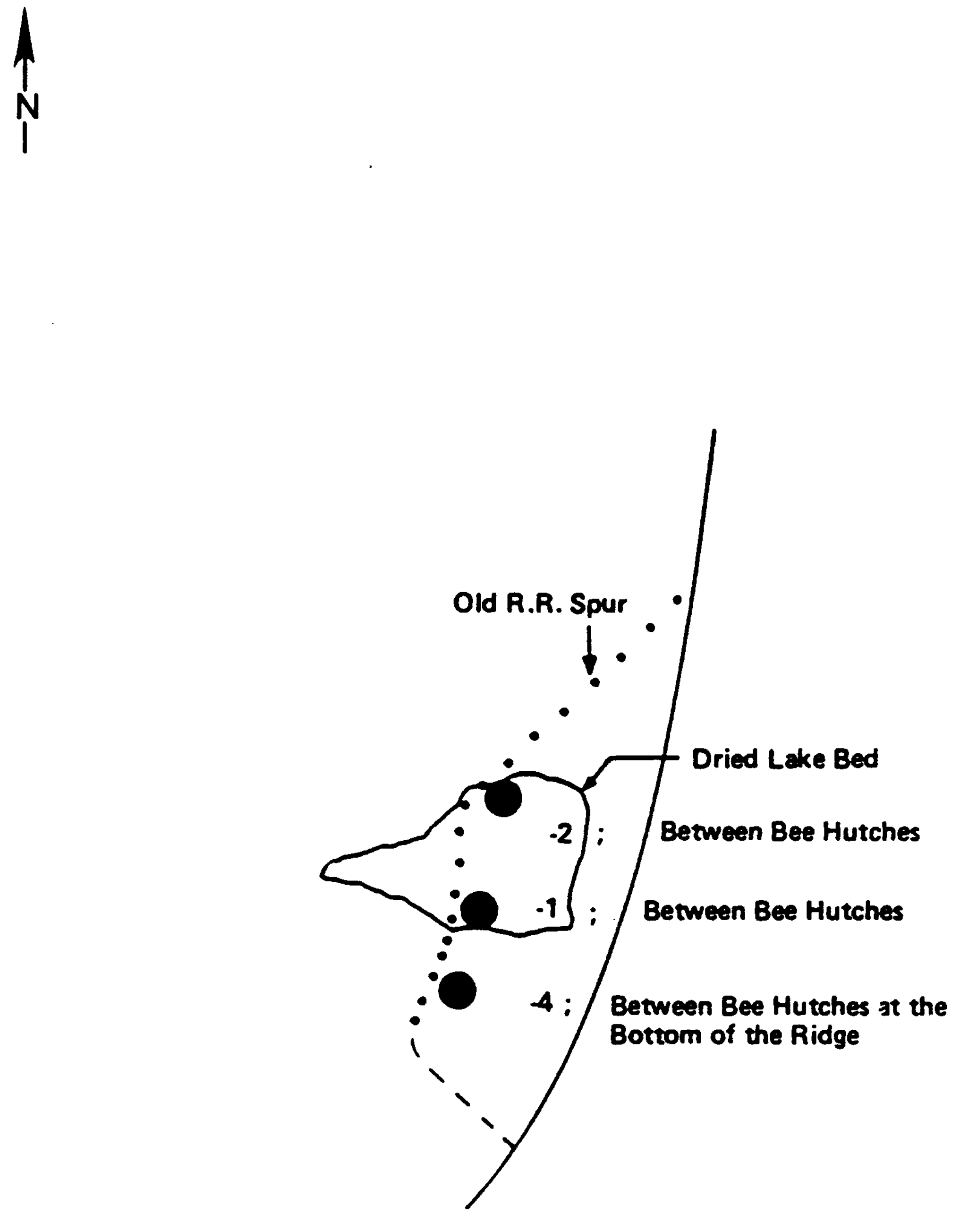


FIGURE B-3. MEASUREMENT POINTS AT CAMP 5 (C5); 2C5-1, 2, 4.

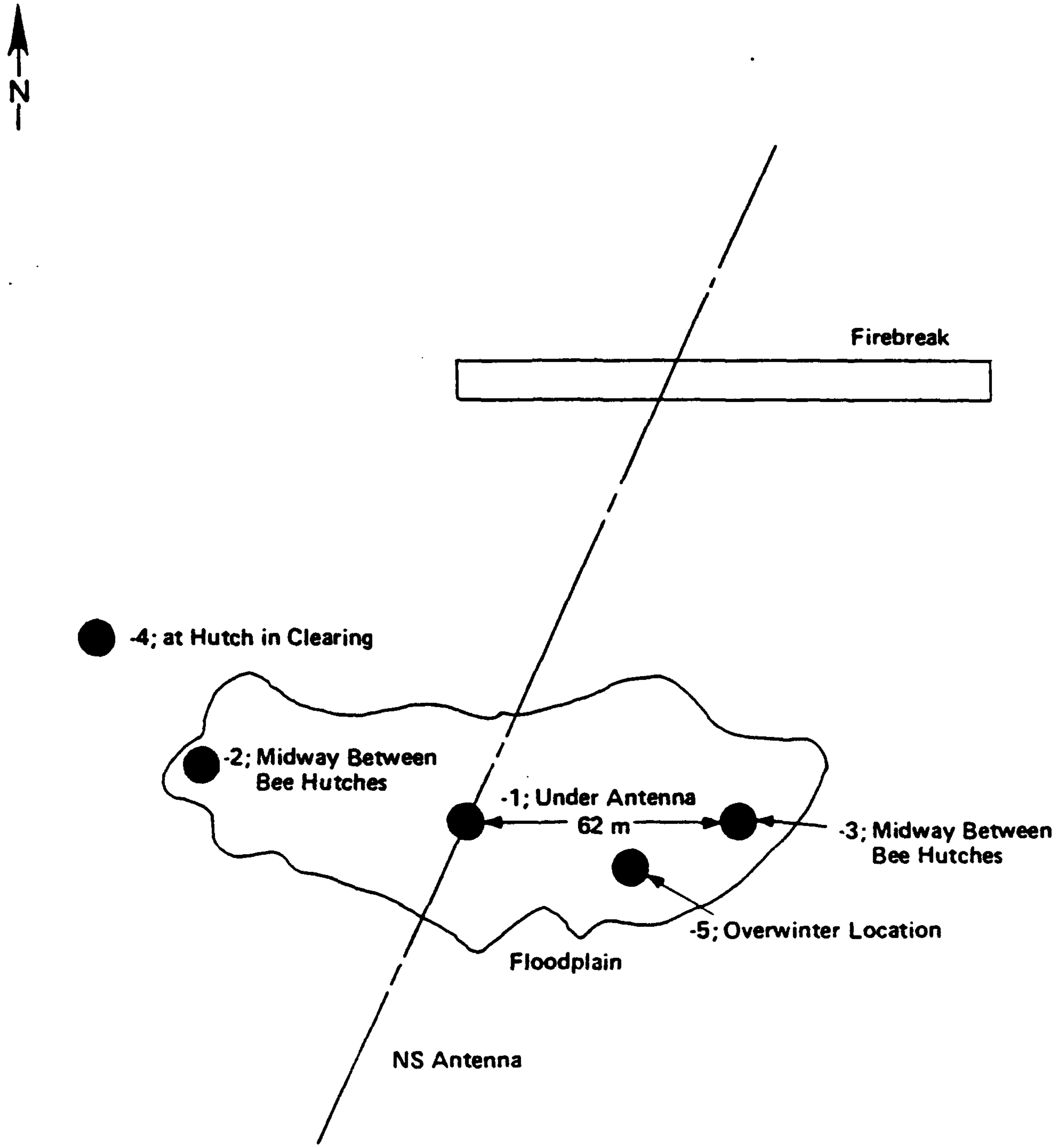


FIGURE B-4. MEASUREMENT POINTS AT FORD 1 (F1); 2T1-1, 2, 3, 4, 5.

60297/790

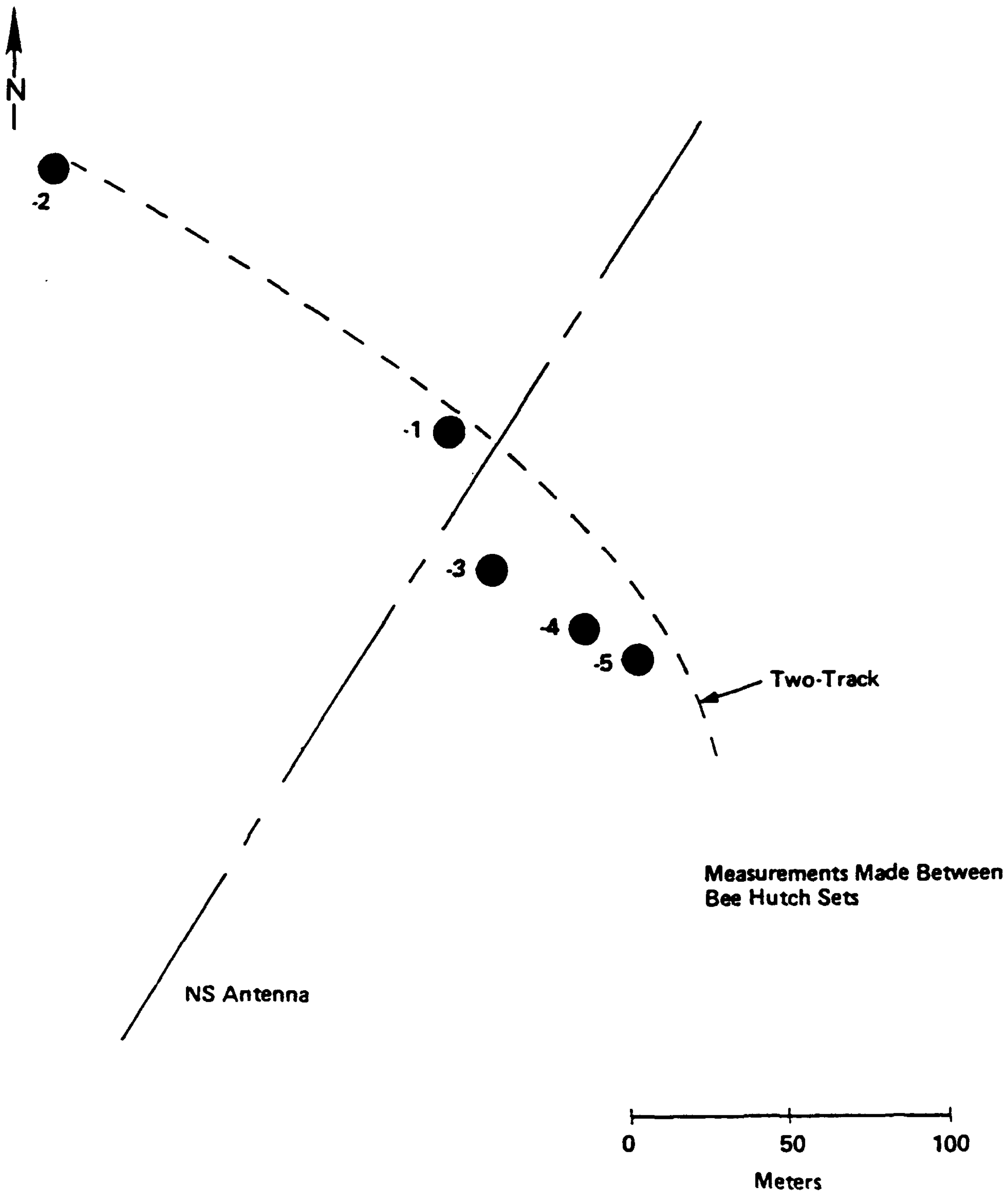


FIGURE B-5. MEASUREMENT POINTS AT FORD 2 (F2); 2T2-1 THROUGH 5.

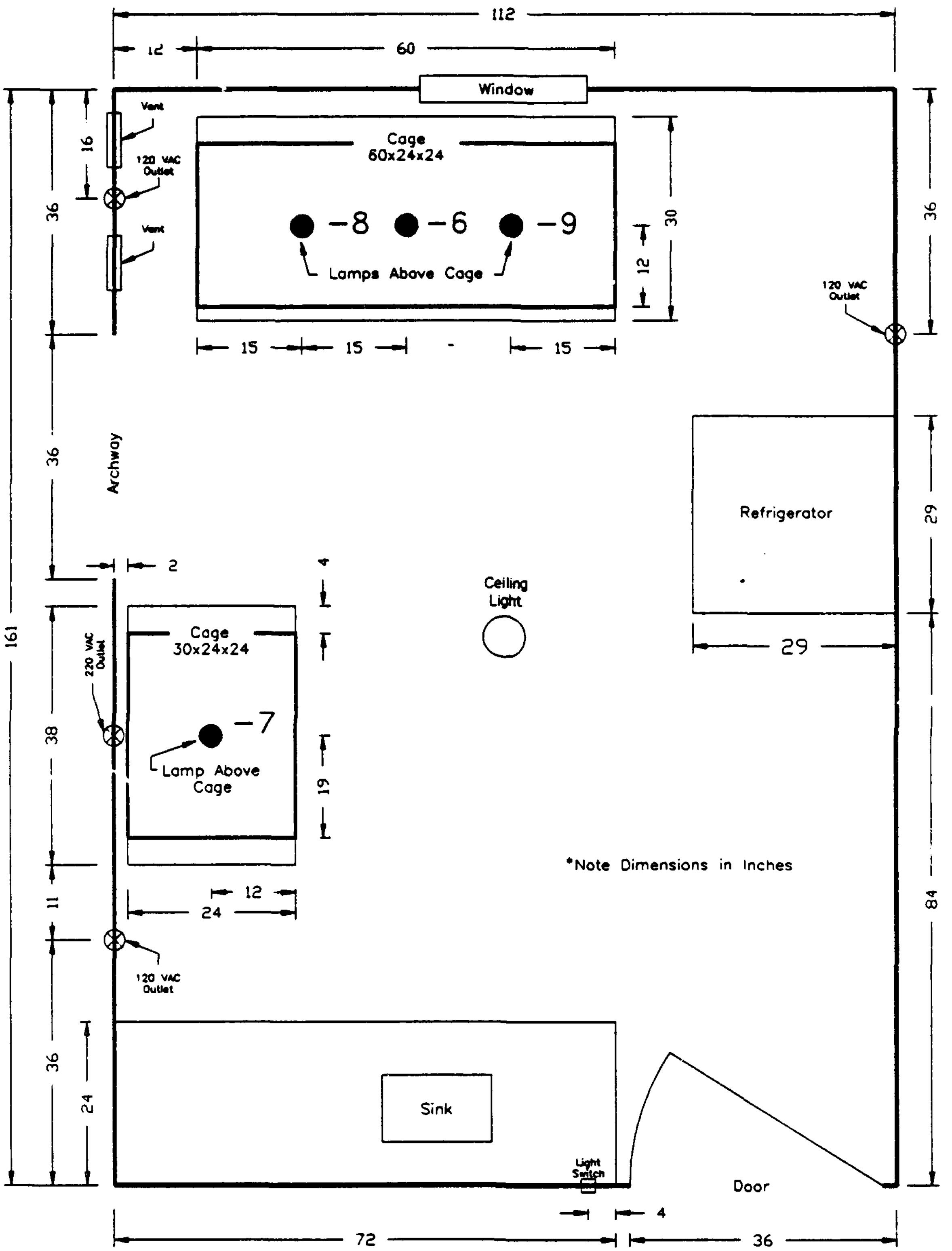


FIGURE B-6. MEASUREMENT POINTS AT CRYSTAL FALLS LABORATORY, 2ND FLOOR WORK AREA; 2L1-6 THROUGH 9.

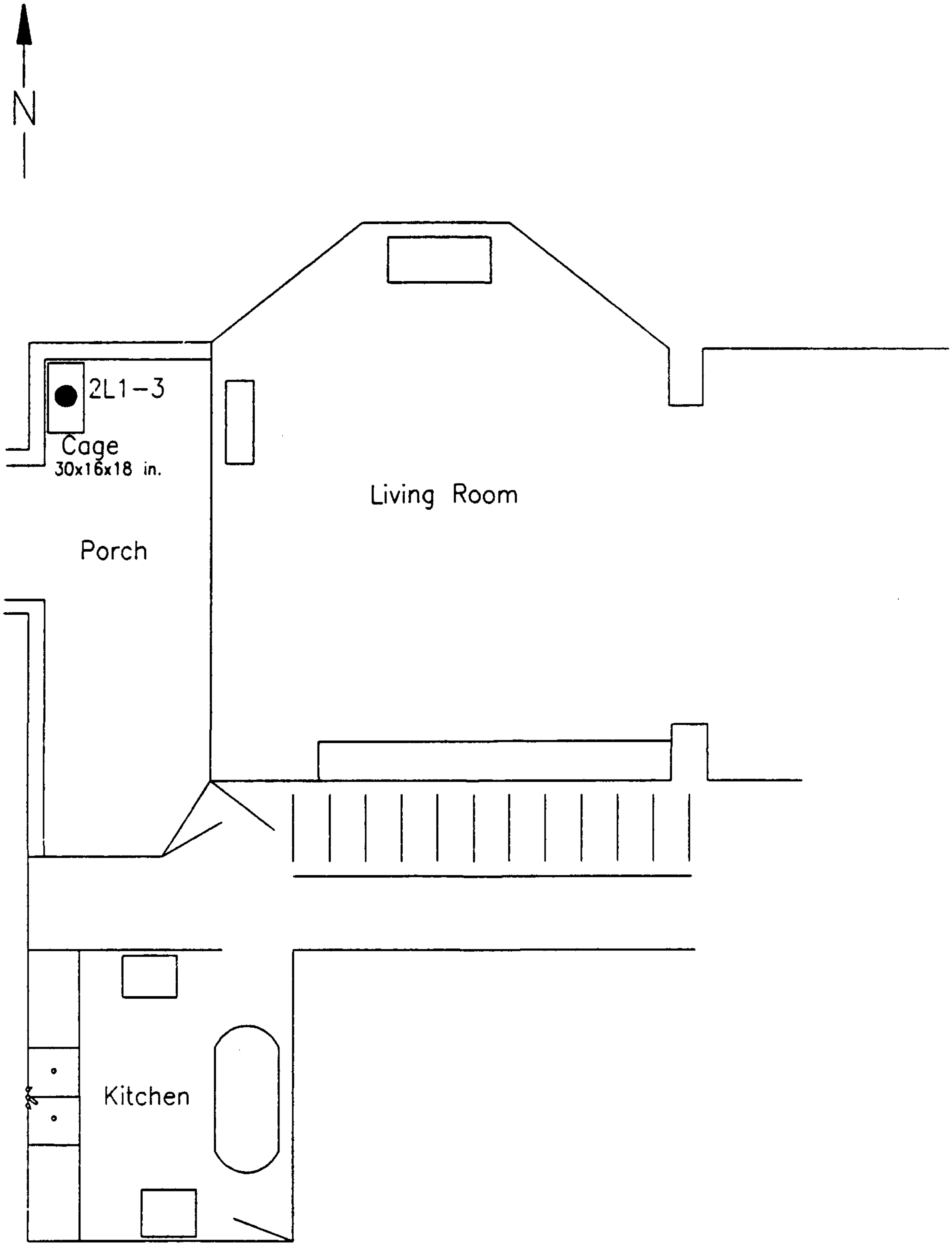


FIGURE B-7. MEASUREMENT POINT AT CRYSTAL FALLS LABORATORY, GROUND LEVEL; 2L1-3.

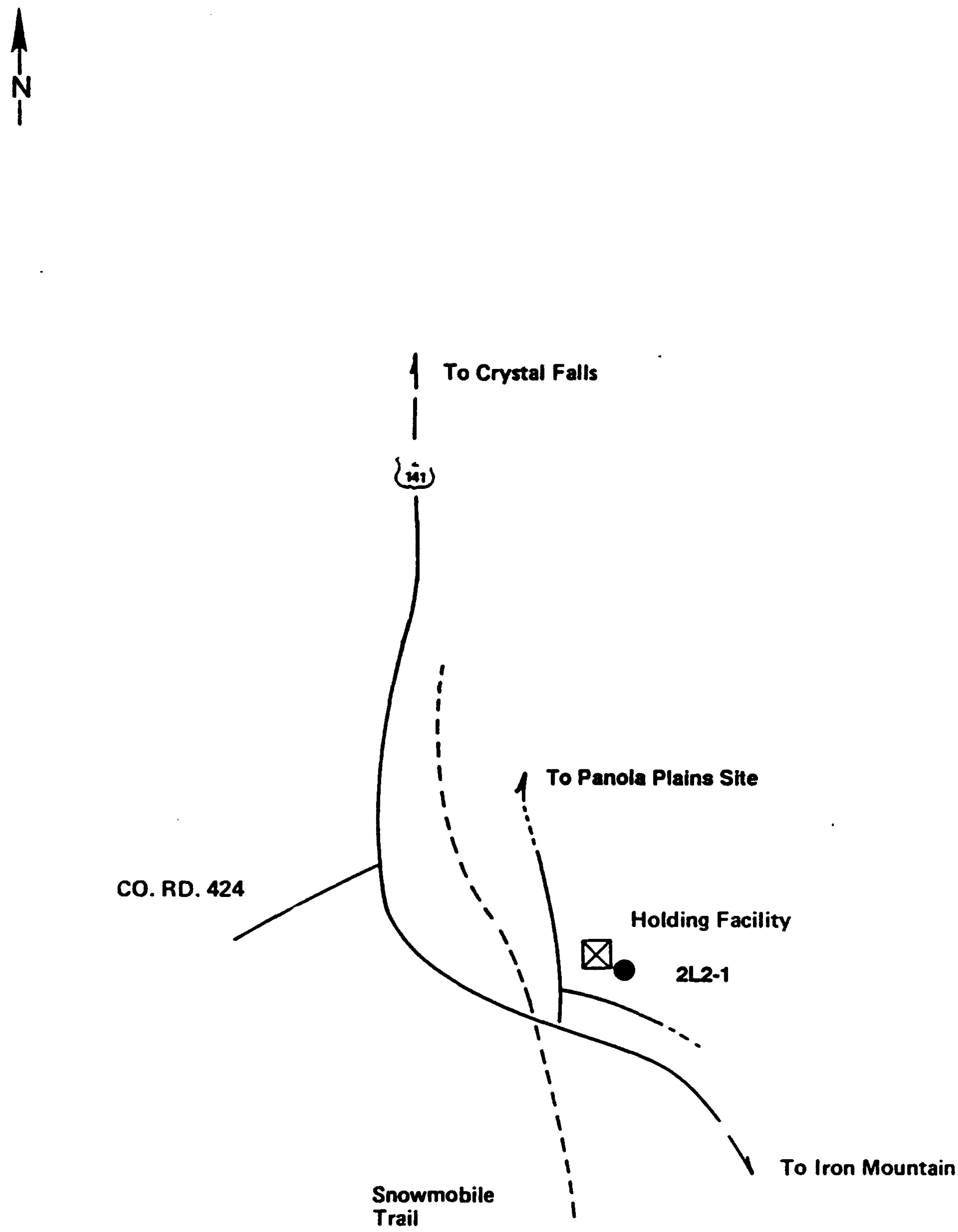


FIGURE B-8. MEASUREMENT POINT AT REMOTE HOLDING FACILITY; 2L2-1.

60297/790

TABLE B-3. 60 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Native Bees Studies

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991
2C4-1	<0.001	<0.001	<	<	<	<	<	<[d]	<[d]
2C4-2	-	-	<	<	<	<	<	<[d]	<[d]
2C5-1	-	<0.001	<	<	<	<	<	<[d]	<[d]
2C5-2	-	<0.001	<	<	<	<	<	<[d]	/
2C5-4	-	-	<	<	<	<	<	<[d]	<[d]
2L2-1	-	-	-	-	-	<	<	<[d]	<[d]
2T1-1	0.004	<0.001	<	<	0.074	0.13	#	0.043[b]	0.20[b]
2T1-2	-	-	-	<	<0.001	0.001	#	<0.001[b]	0.002[b]
2T1-3	-	-	-	<	<0.001	0.001	#	<0.001[b]	0.002[b]
2T1-4	-	-	-	-	<	<0.001	#	<[b]	/
2T1-5	-	-	-	-	<	0.006	#	0.001[b]	0.008[c]
2T2-1	<0.001	<0.001,0.001	<	<	0.024	0.079	#	0.024,0.048[b,c]	/
2T2-2	-	-	-	<	<0.001	<0.001	#	<[b]	/
2T2-3	-	-	-	<	0.023	0.087	#	0.018[b]	/
2T2-4	-	-	-	<	0.003	0.012	#	0.002[b]	/
2T2-5	-	-	-	<	0.002	0.005	#	0.001[b]	/

a = antennas not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 A current.

\- = measurement point not established.
\# = measurement precluded by antenna operation.
< = measurement est. <0.001 V/m based on earth E-field.
/ = measurement not taken.

TABLE B-4. 60 Hz EARTH ELECTRIC FIELD INTENSITES (mV/m)
Native Bees Studies

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991
2C4-1	0.011	0.102,0.138,0.160	0.104	0.133	0.178	0.134	0.095	0.098[d]	0.086[d]
2C4-2	-	-	0.21	0.21	0.26	0.23	0.169	0.095[d]	0.125[d]
2C5-1	-	0.64,0.50,0.93	0.69	0.49	0.38	0.23	0.21	0.37[d]	0.273[d]
2C5-2	-	0.23	0.40	0.160	0.23	0.099	0.139	0.26[d]	/
2C5-4	-	-	0.148	0.090	0.098	0.078	0.078	0.145[d]	0.125[d]
2L2-1	-	-	-	-	-	0.019	0.022,0.013	0.022[d]	0.015[d]
2T1-1	0.23	0.26	0.22	0.042	0.092	0.108	#	0.062[b]	0.135[b]
2T1-2	-	-	-	0.051	0.034	0.053	#	0.024[b]	0.064[b]
2T1-3	-	-	-	0.077	0.051	0.059	#	0.052[b]	0.26[c]
2T1-4	-	-	-	-	0.040	0.152	#	0.040[b]	0.100[b]
2T1-5	-	-	-	-	0.050	0.151	#	0.023[b]	0.30
2T2-1	0.071	0.65,0.88	0.86,0.88	0.23	0.54	1.49	#	0.38,0.90[b,c]	0.149,0.131[b,c]
2T2-2	-	-	-	0.092	0.100	1.31	#	0.20[b]	0.76[b]
2T2-3	-	-	-	0.123	0.25	0.84	#	0.175[b]	0.166[b]
2T2-4	-	-	-	0.078	0.186	0.67	#	0.161[b]	0.146[b]
2T2-5	-	-	-	0.120	0.23	1.11	#	0.22[b]	0.108[b]

a = antennas not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 A current.

\- = measurement point not established.
\# = measurement precluded by antenna operation.
/ = *measurement not taken.*

TABLE B-5. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Native Bees Studies

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991
2C4-1	0.004	0.003,0.004	0.003	0.003	0.006	0.006	0.005	0.006[d]	0.004[d]
2C4-2	-	-	0.003	0.003	0.005	0.003	0.004	0.005[d]	0.004[d]
2C5-1	-	0.001,0.002	0.002	0.001	0.002	0.001	0.001	0.002[d]	0.001[d]
2C5-2	-	<0.001	0.002	0.001	0.002	0.001	0.001	0.002[d]	/
2C5-4	-	-	0.002	0.002	0.002	0.001	0.001	0.002[d]	0.002[d]
2L2-1	-	-	-	-	-	0.003	0.002,0.002	0.002[d]	0.002[d]
2T1-1	0.001	0.002	0.001	0.038	0.042	0.075	#	0.020[b]	0.112[b]
2T1-2	-	-	-	0.004	0.008	0.012	#	0.004[b]	0.018[b]
2T1-3	-	-	-	0.005	0.019	0.018	#	0.004[b]	0.042[c]
2T1-4	-	-	-	-	0.006	0.010	#	0.001[b]	0.012[b]
2T1-5	-	-	-	-	0.011	0.027	#	0.005[b]	0.051[c]
2T2-1	0.002	0.001	0.001	0.020	0.058	0.134	#	0.033,0.070[b,c]	0.041,0.020[b,c]
2T2-2	-	-	-	0.003	0.008	0.022	#	0.004[b]	0.006,0.007[b,c]
2T2-3	-	-	-	0.015	0.038	0.115	#	0.028[b]	0.037[b]
2T2-4	-	-	-	0.006	0.018	0.058	#	0.012[b]	0.017[b]
2T2-5	-	-	-	0.005	0.013	0.044	#	0.010[b]	0.013[b]

a = antennas not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 A current.

\- = measurement point not established.
= measurement precluded by antenna operation.
/ = measurement not taken.

TABLE B-6. 76 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Native Bees Studies

Site No., Meas. Pt.	1986 NS 4 A	1986 NEW 6 A	1986 SEW 6 A	1986 SEW 10 A, EX	1987 NS 15 A	1987 EW 15 A	1988 NS 75 A	1988 EW 75 A	1989 B 150 A	1990 B 150 A	1991 B 150 A
2C4-1	<	<	<	*	<	<	<	<	<	<	<
2C4-2	<	<	<	*	<	<	<	<	<	<	<
2C5-1	<	<	<	*	<	<	<	<	<	<	<
2C5-2	<	<	<	*	<	<	<	<	<	<	/
2C5-4	<	<	<	*	<	<	<	<	<	<	<
2L2-1	-	-	-	-	-	-	<	<	<	<	<
2T1-1	0.59	<	<	*	2.9	0.003	15.8	0.056	23	42	28
2T1-2	0.009	<	<	*	0.022	<	0.135	<0.001	0.23	0.46	0.31
2T1-3	0.005	<	<	*	0.019	<	0.095	0.001	0.178	0.40	0.23
2T1-4	-	-	-	-	0.007	<	0.027	0.001	0.054	0.075	0.073
2T1-5	-	-	-	-	/	/	0.39	0.002	0.63	1.23	0.92
2T2-1	0.182	<	<	*	0.48	<0.001	2.4	0.010	4.9	6.22	6.7
2T2-2	0.005	<	<	*	0.015	<0.001	0.079	0.001	0.142	0.159	0.145
2T2-3	0.123	<	<	*	0.42	<0.001	2.7	0.002	4.9	4.3	4.2
2T2-4	0.021	<	<	*	0.061	<0.001	0.38	0.002	0.54	0.57	0.62
2T2-5	0.012	<	<	*	0.039	<0.001	0.159	<0.001	0.29	0.32	0.36

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.

\- = measurement point not established.
/ = measurement not taken.
< = measurement est. <0.001 V/m based on earth E-field.
* = data cannot be extrapolated.
A = amperes.

TABLE B-7. 76 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Native Bees Studies

Site No., Meas. Pt.	1986				1987		1988		1989	1990	1991
	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	B 150 A
2C4-1	/	/	/	*	0.006	0.003	0.027	0.017	0.072	0.065	0.060
2C4-2	0.002	0.001	0.001	0.002	0.006	0.004	0.030	0.022	0.105	0.103	0.105
2C5-1	0.008	0.004	0.006	0.010	0.022	0.018	0.112	0.110	0.36	0.33	0.31
2C5-2	/	/	/	*	0.008	0.008	0.041	0.042	0.179	0.197	/
2C5-4	/	/	/	*	0.001	0.005	0.020	0.027	0.114	0.113	0.131
2L2-1	-	-	-	-	-	-	0.006	0.002	0.013	0.020	0.010
2T1-1	1.97	0.064	0.108	0.180	8.2	0.23	4	0.77	70	54	44
2T1-2	1.08	0.037	0.070	0.117	3.3	0.21	3.1	0.98	32	38	32
2T1-3	1.31	0.051	0.101	0.168	5.2	0.33	3	1.40	45	53	54
2T1-4	-	-	-	-	4.5	0.191	0	1.38	59	67	67
2T1-5	-	-	-	-	/	/	2	0.96	36	26	61
2T2-1	5.4	0.159	0.086	0.143	32.	0.25	2	1.03	169	122	98
2T2-2	1.63	0.054	0.067	0.112	6.0	0.178	7	1.41	120	177	69
2T2-3	3.0	0.087	0.063	0.105	13.5	0.21	6	0.76	147	139	98
2T2-4	1.93	0.053	0.071	0.118	10.4	0.25	3	1.04	95	85	97
2T2-5	3.6	0.101	0.096	0.160	14.0	0.24	5	1.05	188	145	160

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.

\- = measurement point not established.
/ = measurement not taken.
* = data cannot be extrapolated.
A = amperes.

TABLE B-8. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Native Bees Studies

Site No., Meas. Pt.	1986				1987		1988		1989	1990	1991
	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	B 150 A
2C4-1	/	/	/	*	0.001	<0.001	0.002	0.001	0.006	0.006	0.006
2C4-2	<0.001	<0.001	<0.001	*	0.001	<0.001	0.003	0.001	0.006	0.007	0.007
2C5-1	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.001	0.001	0.002	0.003	0.002
2C5-2	/	/	/	*	<0.001	<0.001	0.001	0.001	0.002	0.003	/
2C5-4	/	/	/	*	<0.001	<0.001	0.001	0.001	0.003	0.003	0.003
2L2-1	-	-	-	-	-	-	<0.001	<0.001	0.002	0.002	0.002
2T1-1	0.77	0.024	0.004	0.007	3.1	0.004	14.4	0.052	31	29	27
2T1-2	0.125	0.004	<0.001	*	0.46	0.002	2.1	0.007	4.5	4.5	4.4
2T1-3	0.131	0.004	0.001	0.002	0.53	0.001	2.5	0.014	5.1	5.2	4.9
2T1-4	-	-	-	-	0.33	0.002	1.47	0.006	3.0	3.0	2.9
2T1-5	-	-	-	-	/	/	3.2	0.016	6.6	6.4	6.1
2T2-1	0.40	0.013	0.002	0.003	1.51	0.004	7.2	0.021	14.7	14.7	13.5
2T2-2	0.060	0.002	<0.001	*	0.22	0.002	1.05	0.005	2.1	2.1	2.1
2T2-3	0.35	0.011	0.002	0.003	1.33	0.002	6.2	0.026	12.8	12.8	11.8
2T2-4	0.158	0.005	0.001	0.002	0.58	0.001	2.9	0.015	5.5	5.7	5.5
2T2-5	0.124	0.004	0.001	0.002	0.46	0.001	2.2	0.013	4.4	4.4	4.4

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.
- = measurement point not established.
/ = measurement not taken.
* = data cannot be extrapolated.
A = amperes.

TABLE B-9. 60 Hz AIR ELECTRIC FIELD INTENSITIES
Native Bees Studies Laboratory

Measurement Point Identification	1988	1989	1990			
	E-Field, V/m	E-Field, V/m	Hatches	Lamps	Workers	E-Field, V/m
2L1-1	79	31	N/A	N/A	N/A	--
2L1-2	22	19.5	N/A	N/A	N/A	--
2L1-3	0.25	0.45	Closed	N/A	N/A	0.001
			Open	N/A	N/A	0.023
2L1-4	-	12.5	N/A	N/A	N/A	--
2L1-5	-	18.2	N/A	N/A	N/A	--
2L1-6	-	5.3	N/A	On	None	14.9
2L1-7 (no cage)	-	-	N/A	N/A	N/A	22
2L1-7 (no cage)	-	-	Closed	On	None	0.039
			Open	On	None	1.14
			Open	On	2-Not grounded to cage	15.7
			Open	On	1-Grounded to cage	0.122-0.198
2L1-8	-	-	Closed	On	None	0.039
			Open	On	None	0.84
			Open	On	2-Grounded to cage	0.122-0.198
2L1-9	-	-	Closed	On	None	0.040
			Open	On	None	0.88
			Open	On	2-Grounded to cage	0.122-0.198

- = measurement point not established.
-- = measurement point dropped.
N/A = not applicable.

TABLE B-10. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Native Bees Studies Laboratory

Measurement Point Identification	1988	1989	1990
2L1-1	0.93	0.75	--
2L1-2	0.52	0.39	--
2L1-3	0.37	0.43	0.33
2L1-4	-	0.32	--
2L1-5	-	0.32	--
2L1-6	-	0.30	/
2L1-7	-	-	0.26
2L1-8	-	-	0.38
2L1-9	-	-	0.40

- = measurement point not established.
-- = measurement point dropped.
/ = data not taken.

APPENDIX C

SOIL ARTHROPODS AND EARTHWORMS STUDIES

SOIL ARTHROPODS AND EARTHWORMS STUDIES

These studies monitor the species composition, population age structure, and distribution of soil arthropods and earthworms. The electric and magnetic fields in the earth are considered the most important electromagnetic (EM) factors influencing soil biota. The electric field in the air is not expected to have a significant impact on the objectives of these studies.

IITRI field crews made ELF EM field measurements at 18 measurement points within the treatment site, control site, and two candidate species collection sites for the soil arthropods and earthworms studies in 1991. The measurement regime differed from 1990 in that one measurement point (3C5-3) was added at the control site and seven measurement points (3T2-7 through 13) were added at the treatment site in support of the earthworm incubation bag study. Measurement points 3S1-1 and 3S2-1 were also added in 1991 at the candidate species collection sites. Measurement dates for 1991 and previous years appear in Table C-1.

The positions of the four sites relative to the NRTF-Republic are shown on the composite map in Figure C-1. The site numbers listed on the map are those used by IITRI. Table C-2 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites. Details of measurement locations within sites are shown in Figures C-2 through C-5.

EM field measurements for 1991 and previous years are found in Tables C-3 through C-8. Tables C-3, C-4, and C-5 present 60 Hz data for the air electric field, earth electric field, and magnetic flux density, respectively. Tables C-6, C-7, and C-8 present 76 Hz data for these fields as well as the corresponding operating currents of the NRTF-Republic for each year.

TABLE C-1. EM FIELD MEASUREMENT DATES
Soil Arthropods and Earthworms Studies

Year	Measurement Dates	
1983	Jun 6	Jul 13
1984	May 14, 21	Aug 9, 13
1985	Jul 19	
1986	Oct 2, 7	
1987	Sep 25, 28	
1988	Sep 26	Oct 3
1989	Sep 13, 15	
1990	Oct 2, 8	
1991	May 6, 7, 8, 30	

TABLE C-2. SITE NUMBER CROSS-REFERENCE
Soil Arthropods and Earthworms Studies

IITRI Site No.	Investigator's Site Name	Location		
		Township	Range	Section(s)
3T2	South Silver Lake	T44N	R29W	25
3C5	Turner Road	T43N	R30W	11
3S1	Merriman Truck Road	T41N	R29W	22
3S2	Firetower Road	T44N	R30W	24

Considerable year-to-year variability in the 60 Hz EM fields is evident. The primary factors in this variability are changes in power line loading conditions (which are unknown) and differences in the configuration of the antennas at the time of measurement. Notes on the antenna configurations are included in the tables primarily for engineering use. The 60 Hz measurements in 1986-1991 (excluding 1989) were taken while the antennas were off, and are representative of 60 Hz levels present during maintenance periods. In 1989, measurements were taken at the treatment site during full-power operation of the antennas with an unmodulated signal. These values indicate that 60 Hz EM fields present during operation of the antennas are comparable to those present when the antennas are off.

Annual variations in the 60 Hz fields measured at the control study sites are also caused by differences in power line loading, but are not dependent on the antennas or their configuration because of the distance of these sites from the antennas. The 60 Hz field values at the control site, nonetheless, are about as variable as those at the treatment site.

Overall, the 60 Hz EM fields measured at both study sites in 1991 are consistent with previous field values and with the expected differences in power line loads and the antenna configuration. Regardless of the field variability associated with the measurement condition, 76 Hz EM fields at the treatment site consistently dominate the 60 Hz EM fields at both the treatment and control sites, and the ratios of 60 Hz EM fields between the treatment and control sites continue to meet exposure criteria guidelines established at the beginning of the study.

The 76 Hz EM field measurements in 1991 were made during operation of either the NS antenna only or both antennas with 150-ampere currents, the predominant operating current of the NRTF-Republic since 4 May 1989. The antenna currents at which measurements were made in each year are given in the column headings of the Tables C-6 through C-8. The annual increases in field magnitudes reflect the level of antenna currents at the time of measurement: 4 or 6 amperes in 1986, 15 amperes in 1987, 75 amperes in 1988, and 150 amperes in 1989, 1990, and 1991. The 1991 measurements taken during operation of both antennas are consistent with the 1989 and 1990 measurements taken under the same conditions, and proportional to the 1986, 1987, and 1988 measurements made at lower currents. Measurements taken

during operation of the NS antenna only include the seven new locations at the treatment site for which there are no previous measurements for comparison and three locations at the control site. Reductions of up to 10% are predicted for EM fields at the treatment site during the EW shutdown based on 1988 measurements during individual operation of the two antennas. Comparison of measurements at the control site with 1989-1990 data indicates only a slight (20%) decrease in magnetic flux density during the EW shutdown, and no apparent change in the electric field intensities. However, any reduction in the 76 Hz EM fields at control sites, where low intensities are desired, should not be of great concern as this situation actually improves the 76 Hz EM ratios between treatment and control sites.

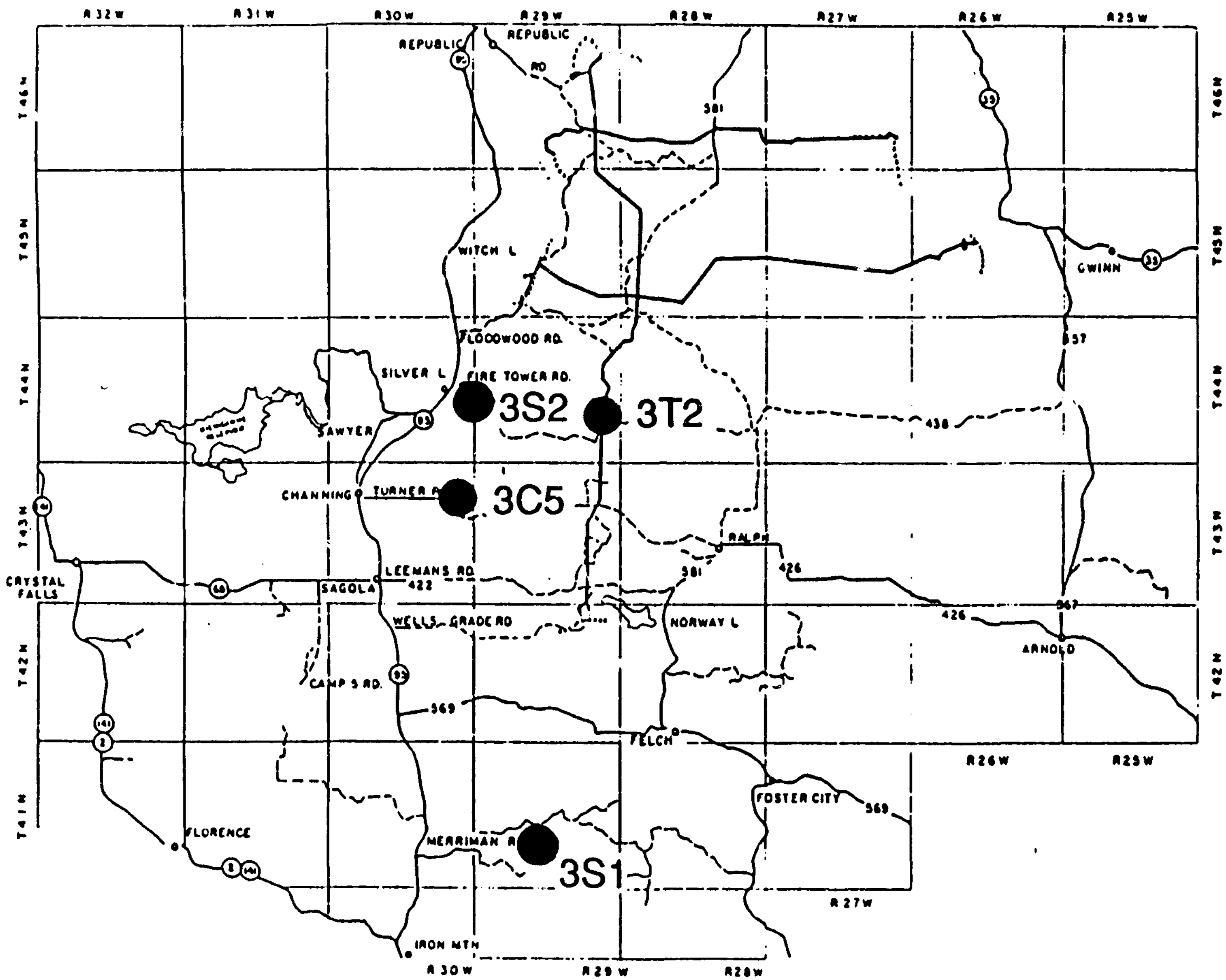


FIGURE C-1. POSITIONS OF SOIL ARTHROPODS AND EARTHWORMS STUDY SITES RELATIVE TO NRTF-REPUBLIC ANTENNA ELEMENTS.

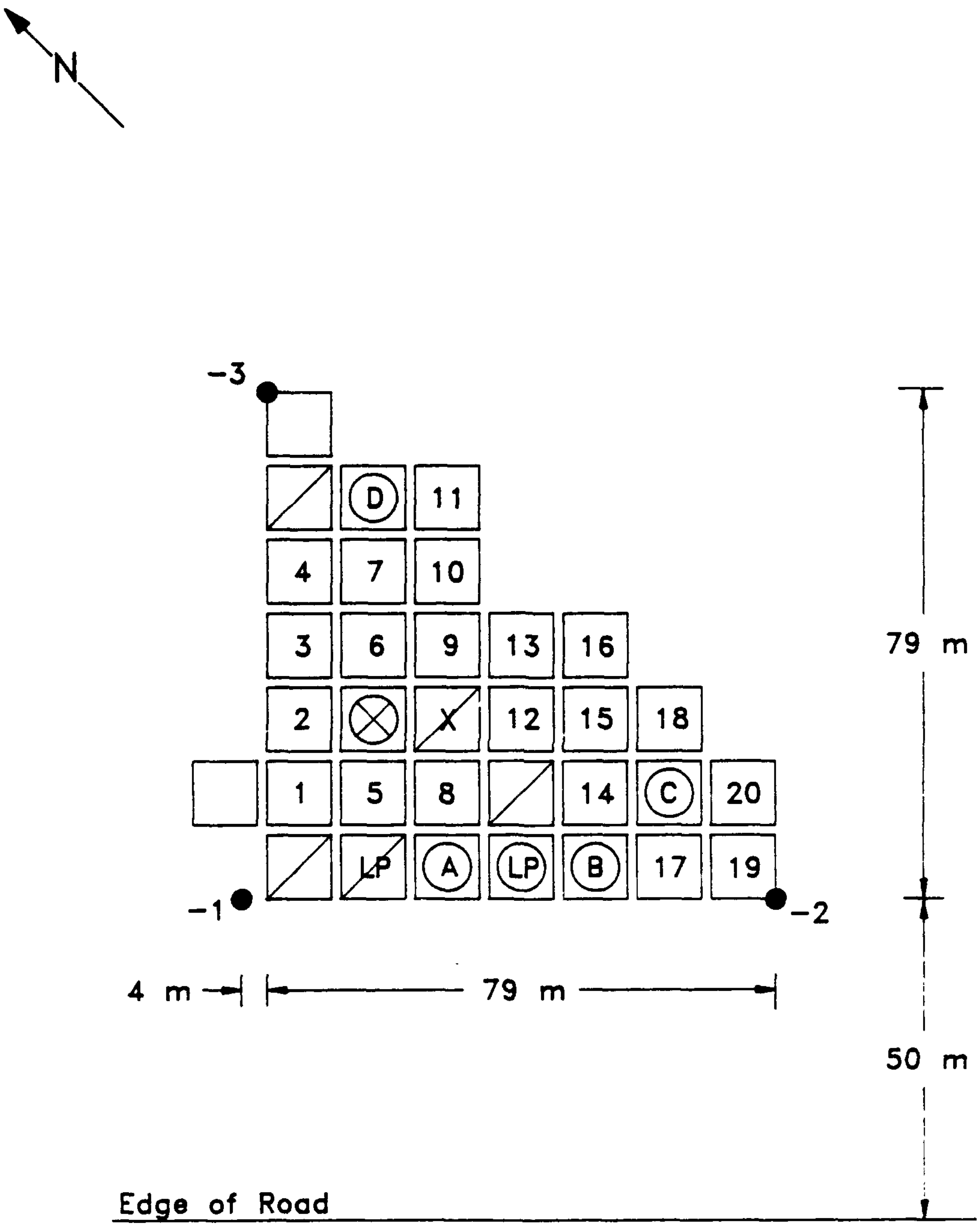


FIGURE C-2. MEASUREMENT POINTS AT TURNER ROAD; 3C5-1 THROUGH 3.

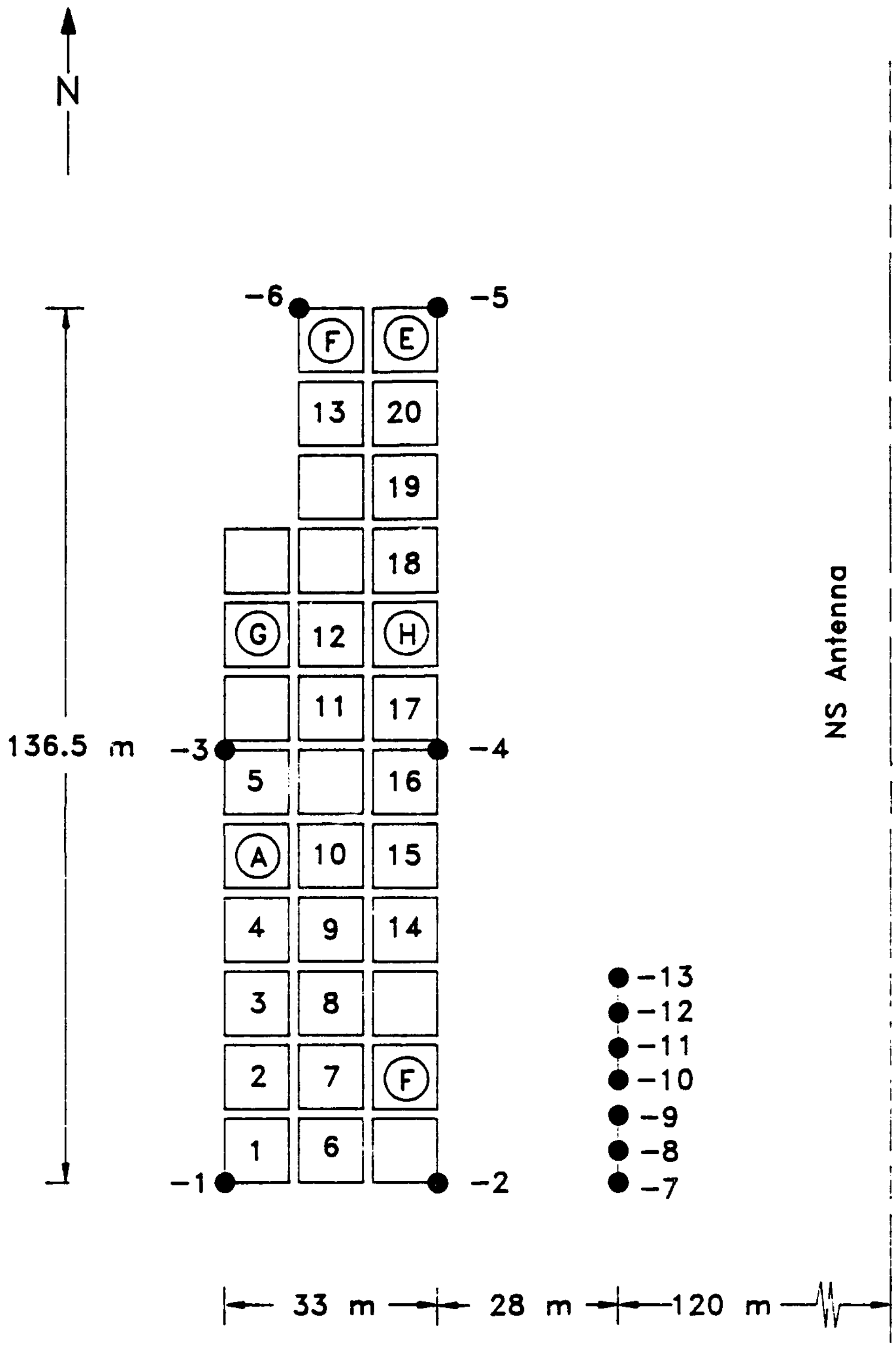


FIGURE C-3. MEASUREMENT POINTS AT SOUTH SILVER LAKE; 3T2-1 THROUGH 13.

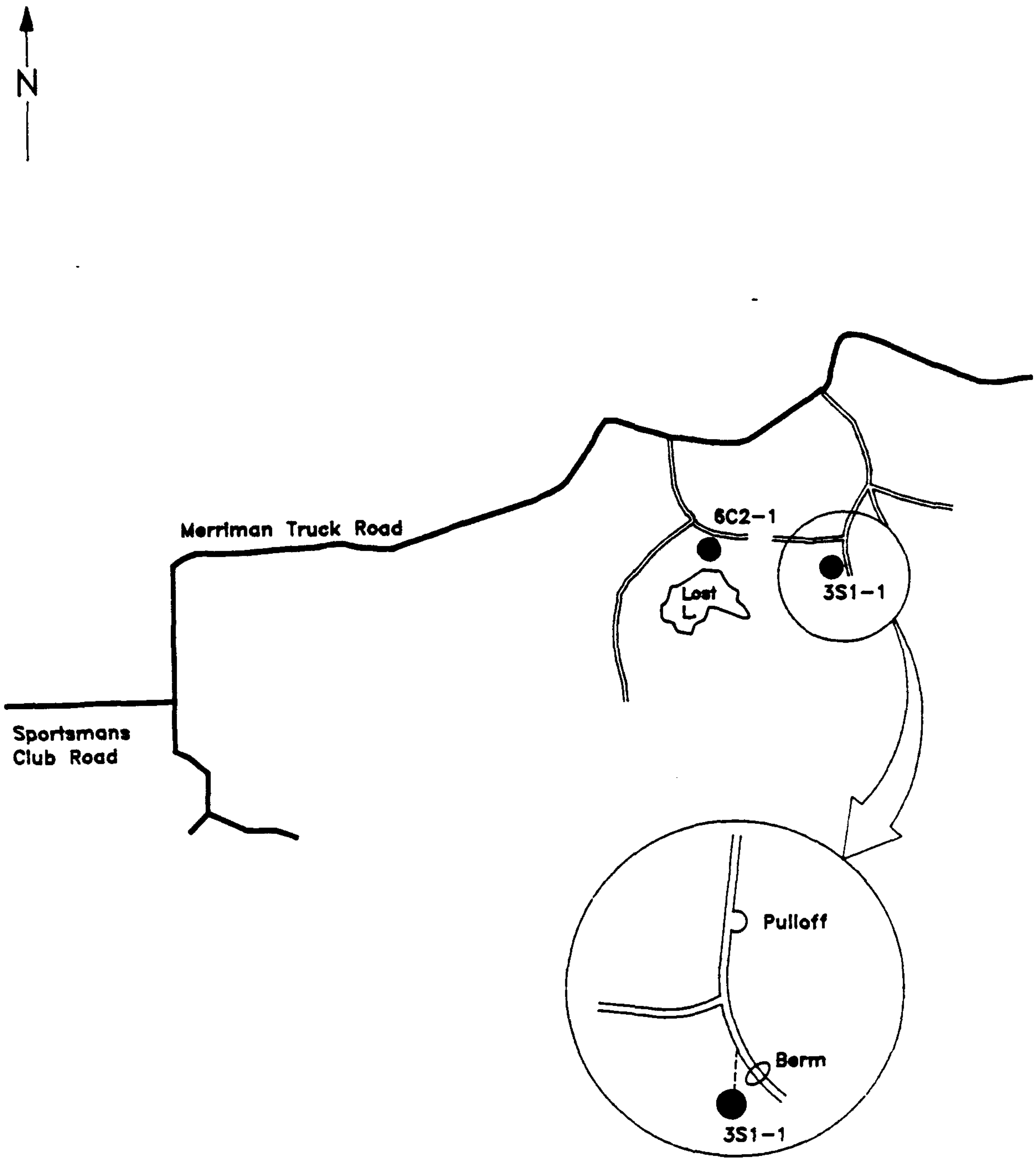


FIGURE C-4. MEASUREMENT POINT AT MERRIMAN TRUCK ROAD WORM COLLECTION SITE; 3S1-1.

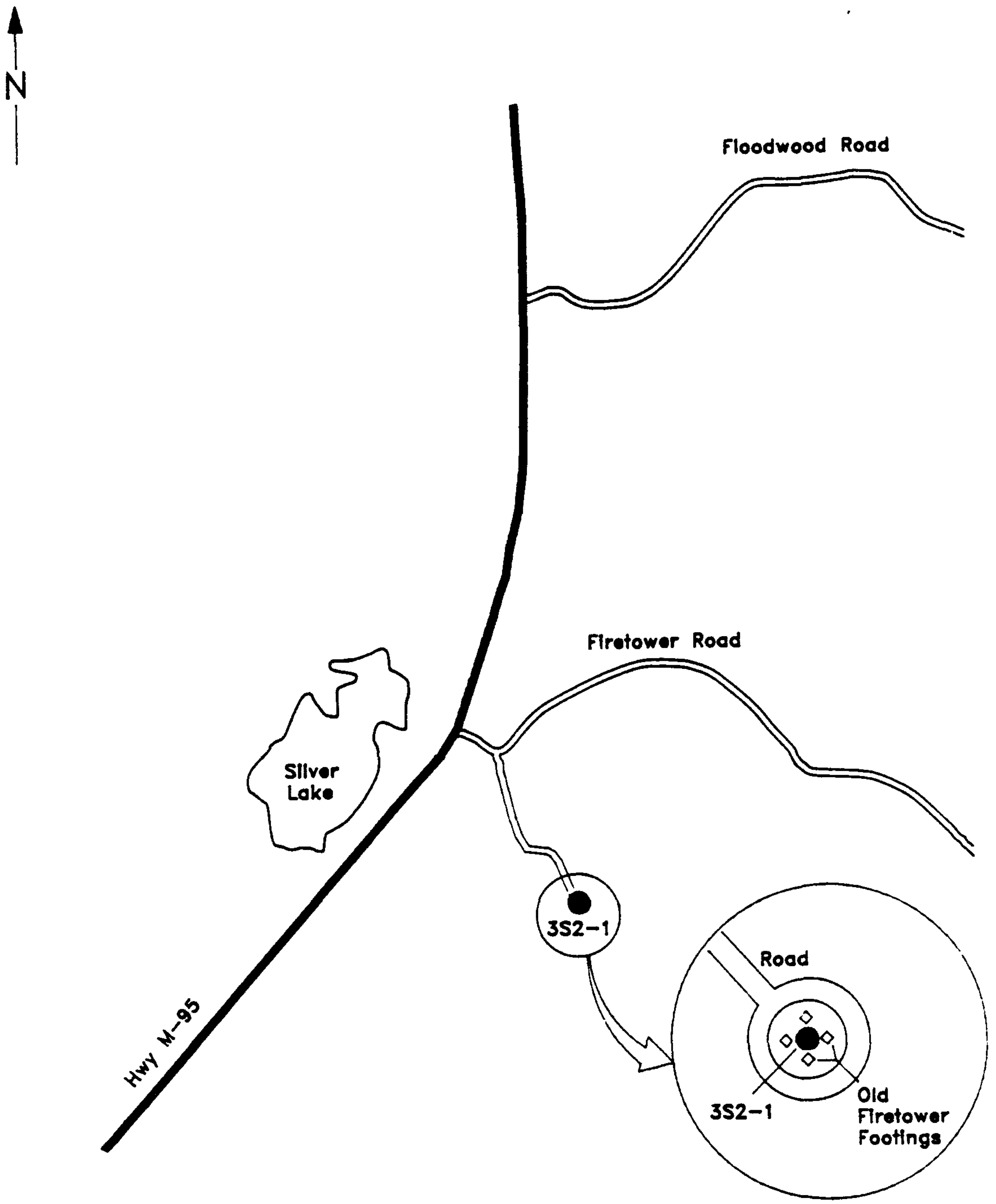


FIGURE C-5. MEASUREMENT POINT AT FIRETOWER ROAD WORM COLLECTION SITE; 3S2-1.

TABLE C-3. 60 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Soil Arthropods and Earthworms Studies

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991
3C5-1	<0.001	<0.001	<	<	<	<	<	<[d]	<[d]
3C5-2	-	-	-	<	<	<	<	<[d]	<[d]
3C5-3	-	-	-	-	-	-	-	-	<[d]
3T2-1	<0.001	<0.001	<	<	<	<	<0.001	<0.001[c]	<[c]
3T2-2	-	-	-	<	<	<	<	<0.001[c]	<[c]
3T2-3	-	-	-	<	<	<	<	<[c]	<[c]
3T2-4	-	-	-	<	<	<	<	<[c]	<[c]
3T2-5	-	-	-	<	<	<	<	<[c]	<[c]
3T2-6	-	-	-	<	<	<	<	<[c]	<[c]
3T2-7	-	-	-	-	-	-	-	-	/
3T2-8	-	-	-	-	-	-	-	-	/
3T2-9	-	-	-	-	-	-	-	-	/
3T2-10	-	-	-	-	-	-	-	-	/
3T2-11	-	-	-	-	-	-	-	-	/
3T2-12	-	-	-	-	-	-	-	-	/
3T2-13	-	-	-	-	-	-	-	-	/
3S1-1	-	-	-	-	-	-	-	-	<[c]
3S2-1	-	-	-	-	-	-	-	-	<[c]

a = antennas not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 A current.

\- = measurement point not established.
< = measurement est. <0.001 V/m based on earth E-field.
/ = measurement not taken.

TABLE C-4. 60 Hz EARTH ELECTRIC FIELD INTENSITES (mV/m)
Soil Arthropods and Earthworms Studies

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991
3C5-1	0.063	0.018,0.032	0.036	0.027	0.054	0.054	0.062	0.065[d]	0.069[d]
3C5-2	-	-	-	0.027	0.071	0.085	0.182	0.118[d]	0.098[d]
3C5-3	-	-	-	-	-	-	-	-	0.120[d]
3T2-1	0.106	0.129,0.27	0.194	0.045	0.042	0.091	0.055	0.042[c]	0.050[c]
3T2-2	-	-	-	0.068	0.049	0.093	0.049	0.043[c]	0.063[c]
3T2-3	-	-	-	0.038	0.043	0.084	0.035	0.047[c]	0.041[c]
3T2-4	-	-	-	0.045	0.039	0.087	0.068	0.040[c]	0.176[c]
3T2-5	-	-	-	0.044	0.045	0.084	0.053	0.047[c]	0.047[c]
3T2-6	-	-	-	0.048	0.033	0.087	0.041	0.042[c]	0.043[c]
3T2-7	-	-	-	-	-	-	-	-	/
3T2-8	-	-	-	-	-	-	-	-	/
3T2-9	-	-	-	-	-	-	-	-	/
3T2-10	-	-	-	-	-	-	-	-	/
3T2-11	-	-	-	-	-	-	-	-	/
3T2-12	-	-	-	-	-	-	-	-	/
3T2-13	-	-	-	-	-	-	-	-	/
3S1-1	-	-	-	-	-	-	-	-	0.62[c]
3S2-1	-	-	-	-	-	-	-	-	0.45[c]

a = antennas not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 A current.

\- = measurement point not established.
/ = measurement not taken.

TABLE C-5. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Soil Arthropods and Earthworms Studies

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991
3C5-1	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.002[d]	0.002[d]
3C5-2	-	-	-	<0.001	0.001	0.001	0.002	0.001[d]	0.001[d]
3C5-3	-	-	-	-	-	-	-	-	0.001[d]
3T2-1	<0.001	<0.001	0.001	0.005	0.002	0.004	0.001	0.003[c]	0.005[c]
3T2-2	-	-	-	0.006	0.003	0.006	0.002	0.004[c]	0.006[c]
3T2-3	-	-	-	0.004	0.003	0.003	0.001	0.003[c]	0.005[c]
3T2-4	-	-	-	0.005	0.003	0.005	0.002	0.004[c]	0.010[c]
3T2-5	-	-	-	0.005	0.003	0.004	0.002	0.004[c]	0.005[c]
3T2-6	-	-	-	0.004	0.003	0.003	0.001	0.004[c]	0.006[c]
3T2-7	-	-	-	-	-	-	-	-	/
3T2-8	-	-	-	-	-	-	-	-	/
3T2-9	-	-	-	-	-	-	-	-	/
3T2-10	-	-	-	-	-	-	-	-	/
3T2-11	-	-	-	-	-	-	-	-	/
3T2-12	-	-	-	-	-	-	-	-	/
3T2-13	-	-	-	-	-	-	-	-	/
3S1-1	-	-	-	-	-	-	-	-	0.006[c]
3S2-1	-	-	-	-	-	-	-	-	0.004[c]

a = antennas not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 A current.

\- = measurement point not established.
/ = measurement not taken.

TABLE C-6. 76 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Soil Arthropods and Earthworms Studies

Site No., Meas. Pt.	1986				1987		1988		1989	1990	1991
	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	150 A
3C5-1	<	<	<	*	<	<	<	<	<	<	<, NS
3C5-2	<	<	<	*	<	<	<	<	<	<	<, NS
3C5-3	-	-	-	-	-	-	-	-	-	-	<, NS
3T2-1	0.002	<	<	*	0.006	<	0.031	0.003	0.064	0.056	0.067, B
3T2-2	0.002	<	<	*	0.006	<	0.024	0.003	0.070	0.068	0.064, B
3T2-3	0.002	<	<	*	0.006	<	0.028	0.003	0.048	0.067	0.061, B
3T2-4	0.002	<	<	*	0.006	<	0.026	0.003	0.055	0.061	0.054, B
3T2-5	0.002	<	<	*	0.006	<	0.029	0.005	0.061	0.056	0.097, B
3T2-6	0.002	<	<	*	0.006	<	0.027	0.002	0.048	0.05[illegible]	0.053, B
3T2-7	-	-	-	-	-	-	-	-	-	-	/
3T2-8	-	-	-	-	-	-	-	-	-	-	/
3T2-9	-	-	-	-	-	-	-	-	-	-	/
3T2-10	-	-	-	-	-	-	-	-	-	-	/
3T2-11	-	-	-	-	-	-	-	-	-	-	/
3T2-12	-	-	-	-	-	-	-	-	-	-	/
3T2-13	-	-	-	-	-	-	-	-	-	-	/
3S1-1	-	-	-	-	-	-	-	-	-	-	/
3S2-1	-	-	-	-	-	-	-	-	-	-	/

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas
EX = extrapolated data.
A = amperes.

< = measurement est. <0.001 V/m based on earth E-field.
* = data cannot be extrapolated.
- = measurement point not established.
/ = measurement not taken.

TABLE C-7. 76 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Soil Arthropods and Earthworms Studies

Site No., Meas. Pt.	1986				1987		1988		1989	1990	1991
	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	150 A
3C5-1	0.005	0.001	0.002	0.003	0.020	0.006	0.093	0.027	0.22	0.21	0.186, NS
3C5-2	0.009	0.001	0.003	0.005	0.034	0.009	0.170	0.021	0.38	0.29	0.31, NS
3C5-3	-	-	-	-	-	-	-	-	-	-	0.27, NS
3T2-1	1.33	0.057	0.188	0.31	5.4	0.54	27	2.6	58	55	59, B
3T2-2	1.46	0.064	0.24	0.40	6.3	0.71	26	3.0	60	53	55, B
3T2-3	1.19	0.047	0.149	0.25	5.3	0.60	27	2.7	49	56	58, B
3T2-4	1.47	0.060	0.20	0.33	5.6	0.47	29	2.6	62	50	54, B
3T2-5	1.56	0.070	0.23	0.38	5.7	0.61	27	2.8	52	59	62, B
3T2-6	1.20	0.056	0.180	0.30	5.5	0.54	27	2.4	49	49	55, B
3T2-7	-	-	-	-	-	-	-	-	-	-	74, NS
3T2-8	-	-	-	-	-	-	-	-	-	-	68, NS
3T2-9	-	-	-	-	-	-	-	-	-	-	71, NS
3T2-10	-	-	-	-	-	-	-	-	-	-	46, NS
3T2-11	-	-	-	-	-	-	-	-	-	-	56, NS
3T2-12	-	-	-	-	-	-	-	-	-	-	66, NS
3T2-13	-	-	-	-	-	-	-	-	-	-	60, NS
[illegible]	-	-	-	-	-	-	-	-	-	-	/
2-1	-	-	-	-	-	-	-	-	-	-	/

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas.
EX = extrapolated data.
A = amperes.
\- = measurement point not established.
/ = measurement not taken.

TABLE C-8. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Soil Arthropods and Earthworms Studies

Site No., Meas. Pt.	1986				1987		1988		1989	1990	1991
	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	150 A
3C5-1	<0.001	<0.001	<0.001	*	0.002	0.001	0.008	0.003	0.019	0.018	0.014, NS
3C5-2	<0.001	<0.001	<0.001	*	0.002	0.001	0.007	0.002	0.017	0.017	0.014, NS
3C5-3	-	-	-	-	-	-	-	-	-	-	0.012, NS
3T2-1	0.048	0.001	0.001	0.002	0.187	0.003	0.88	0.012	1.84	1.81	1.73, B
3T2-2	0.060	0.002	0.001	0.002	0.23	0.003	1.11	0.012	2.3	2.2	2.2, B
3T2-3	0.046	0.001	0.001	0.002	0.182	0.002	0.89	0.012	1.81	1.80	1.68, B
3T2-4	0.055	0.002	0.001	0.002	0.23	0.003	1.08	0.012	2.3	2.2	2.3, B
3T2-5	0.057	0.002	0.001	0.002	0.22	0.003	1.03	0.012	2.2	2.1	2.1 B
3T2-6	0.049	0.001	0.001	0.002	0.190	0.003	0.90	0.012	1.88	1.89	1.7[illegible], B
3T2-7	-	-	-	-	-	-	-	-	-	-	2.5, NS
3T2-8	-	-	-	-	-	-	-	-	-	-	2.5, NS
3T2-9	-	-	-	-	-	-	-	-	-	-	2.5, NS
3T2-10	-	-	-	-	-	-	-	-	-	-	2.5, NS
3T2-11	-	-	-	-	-	-	-	-	-	-	2.6, NS
3T2-12	-	-	-	-	-	-	-	-	-	-	2.6, NS
3T2-13	-	-	-	-	-	-	-	-	-	-	2.6, NS
3S1-1	-	-	-	-	-	-	-	-	-	-	/
3S2-1	-	-	-	-	-	-	-	-	-	-	/

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas.
EX = extrapolated data.
A = amperes.

* = data cannot be extrapolated.
\- = measurement point not established.
/ = measurement not taken.

APPENDIX D

UPLAND FLORA AND SOIL MICROFLORA STUDIES

UPLAND FLORA AND SOIL MICROFLORA STUDIES

The major themes of the upland flora and microflora studies are the functional and structural aspects of organic material cycling. These studies investigate and characterize trees, herbaceous plants, and microflora (fungi and streptomycetes) populations. The electric and magnetic fields in the earth are considered important electromagnetic (EM) factors influencing soil biota and processes. The electric and magnetic fields in the air may influence any object extending above the surface of the earth. Because the electric field in the air can be greatly distorted and shielded by trees or plants on a study plot, special care was taken in characterizing the air electric field intensities to avoid such perturbations.

The treatment sites for these studies straddle the EW antenna and one of the grounding elements of the NRTF-Republic; the control site is located more than 28 miles from the nearest antenna element. The antenna treatment site and the control site each consist of three overstory tree plots (pole stands), three plots cleared and planted with red pine seedlings (plantations), and three plots set aside for the study of herbaceous plants (reserves). The ground treatment site consists of only three plots cleared and planted with red pine. No overstory tree plots or herbaceous reserves were established at the ground treatment site because the required buffer strips would have resulted in the biota being at too great a distance from the grounding elements for meaningful EM field exposure. Dropped foliage for decomposition studies are collected at the control site and at two sites in Houghton County.

IITRI field crews made ELF EM field measurements at 50 historic measurement points in 1991 within the two treatment sites, one control site, and three foliage collection points. The study sites and measurement points within those study sites were unchanged from 1990. Annual EM field measurement dates for 1991 and previous years appear in Table D-1.

TABLE D-1. EM FIELD MEASUREMENT DATES
Upland Flora and Soil Microflora Studies

Year	Measurement Dates		
1983	Jun 7, 14		
1984	May 15, 21	Aug 6, 9	
1985	Jul 15, 17, 19		
1986	Oct 1, 2, 14		
1987	Sep 22, 23	Oct 5, 7	
1988	Sep 22	Oct 5-7	
1989	Sep 19	Oct 11, 12	
1990	Jun 27-30	Aug 9	Oct 1
1991	Jun 19, 20	Oct 3, 15-17	

TABLE D-2. SITE NUMBER CROSS-REFERENCE
Upland Flora and Soil Microflora Studies

IITRI Site No.	Investigator's Site Name	Location Township	Range	Section(s)
4T2	Martell's Lake (Overhead): ML	T45N	R29W	28
4T4	Martell's Lake (Buried): EP	T45N	R29W	28
4C1	Paint Pond Road Control	T41N	R32W	3
4S1	Red Maple Leaf Collection	T55N	R35W	21
4S2	Oak Leaf Collection	T41N	R32W	3
4S3	Pine Needle Collection	T54N	R34W	5

The positions of the study sites relative to the NRTF-Republic are shown on the composite map in Figure D-1. The site numbers listed on the map are those used by IITRI. Table D-2 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites. The annual (historic) measurement point locations are shown in Figures D-2 through D-6. Figures D-3 and D-4 also identify data logger (E) and fixed probe (F) measurements locations, many of which coincide with the historic (H) measurement points.

Annual EM field measurements for 1991 and previous years are found in Tables D-3 through D-8. Tables D-3, D-4, and D-5 present 60 Hz data for the air electric field, earth electric field, and magnetic flux density, respectively. Tables D-6, D-7, and D-8 present 76 Hz data for these fields as well as the corresponding operating current of the NRTF-Republic for each year.

Considerable year-to-year variability in the 60 Hz EM fields is evident. The primary factors in this variability at treatment sites are changes in power line loading conditions (which are unknown) and differences in the configuration of the antennas at the time of measurement. Notes on the antenna configurations are included in the tables primarily for engineering use. The 60 Hz measurements at treatment sites in 1986, 1987, 1988, and 1991 were taken while the antennas were off, and are representative of 60 Hz levels present during maintenance periods. In 1989 and 1990, the antenna status (modulated signal) precluded 60 Hz EM field measurements at the treatment sites. However, measurements were possible at treatment sites for other studies in 1989 during unmodulated operation of the antennas. These measurements indicate that 60 Hz EM fields present during operation of the antennas are comparable to those present when the antennas are off.

Annual variations in the 60 Hz fields measured at the control study site are also caused by differences in power line loading, but are not dependent on the antennas or their configuration because of the distance of these sites from the antennas. The 60 Hz field values at the control site are about as variable as those at the treatment sites.

AD-A272 098 ELF COMMUNICATIONS SYSTEM ECOLOGICAL MONITORING 2/4
PROGRAM: ELECTROMAGNETIC FIELD MEASUREMENTS AND
ENGINEERING SUPPORT-1991(U) IIT RESEARCH INST CHICAGO
UNCLASSIFIED IL D P H ET AL. DEC 92 IITRI-TR-D06200-4 NL

Overall, the 60 Hz EM fields measured at all study sites in 1991 are consistent with previous field values and with the expected differences in power line loads and antenna configuration. Regardless of the field variability associated with the measurement condition, 76 Hz EM fields at treatment sites consistently dominate the 60 Hz EM fields at treatment and control sites, and the ratios of 60 Hz EM fields between matched treatment/control sites continue to meet exposure criteria guidelines established at the beginning of the study.

The 76 Hz EM field measurements in 1991 were made with 150 ampere antenna currents, the predominant operating current of the NRTF-Republic since 4 May 1989. The energized antenna elements and currents at the time of measurement are given below the year in the column headings of Tables D-6 through D-8. The annual increases in field magnitudes reflect the level of antenna current at the time of measurement: 4 or 6 amperes in 1986, 15 amperes in 1987, 75 amperes in 1988, and 150 amperes in 1989 and 1991. The 1990 measurement values for full power operation with both antennas are consistent with those obtained in 1990 and 1989 under the same antenna conditions.

The extended shutdown of the EW antenna for repairs had a significant impact on the 76 Hz EM exposure levels at the treatment sites for this study, which are located along the SEW antenna element and ground 5. A complete set of EM field measurements was made at both treatment sites during operation of the NS antenna only. These data are included in Tables D-6 through D-8. It was found that the EM exposures at all locations at the treatment sites were reduced to about one-third of those with both antennas energized. The relatively high levels along the de-energized EW antenna are caused by cross coupling from the energized NS antenna.

Measurements were not made at the control site with the EW antenna shutdown. However, 76 Hz EM field contributions from the NS and EW antennas are known to be of similar magnitude at this site. This is evidenced by the 1987 and 1988 measurements during individual antenna operation. EM exposures at the control, therefore, were likely reduced to about one-half of their normal levels when only the NS antenna was operating. While the actual amount of exposure reduction at the control site is unknown, any reduction in the EM fields here is desirable from the standpoint of maintaining proper EM exposure ratios.

Regular measurements at the fixed electric field probes, which were established at numerous locations at the treatment sites in 1990, are still being conducted. Fixed probe measurements locations are designated by an "F" in the measurement point symbols in Figures D-3 and D-4. All fixed probe locations established in 1990 are still in use. The fixed probe measurement set was expanded in 1991 to include the electrode pairs monitored by the data loggers. Data for all fixed probe measurements in 1990 and 1991 are presented in Tables D-9 through D-12. Measurements made during shutdown of the EW antenna are labeled "NS Only" in the column headings. Summary statistics computed for each probe for each year are also included in these tables. Statistics for 1991 do not include data for NS antenna operation only.

Special efforts were made in 1990 to provide a detailed characterization of the earth electric field gradients at the treatment study sites. Discussion of these data may be found in a previous report.[11] In 1991 additional efforts were made to characterize both the spatial and temporal variability of these fields. EM field profiles comparing annual, fixed probe, and data logger data for these sites are presented in Section 4.3.1.2 of this report. The 1990 earth electric field contour maps for the two treatment sites and the survey data used in their generation are again presented in Figures D-7 through D-10 for convenient reference.

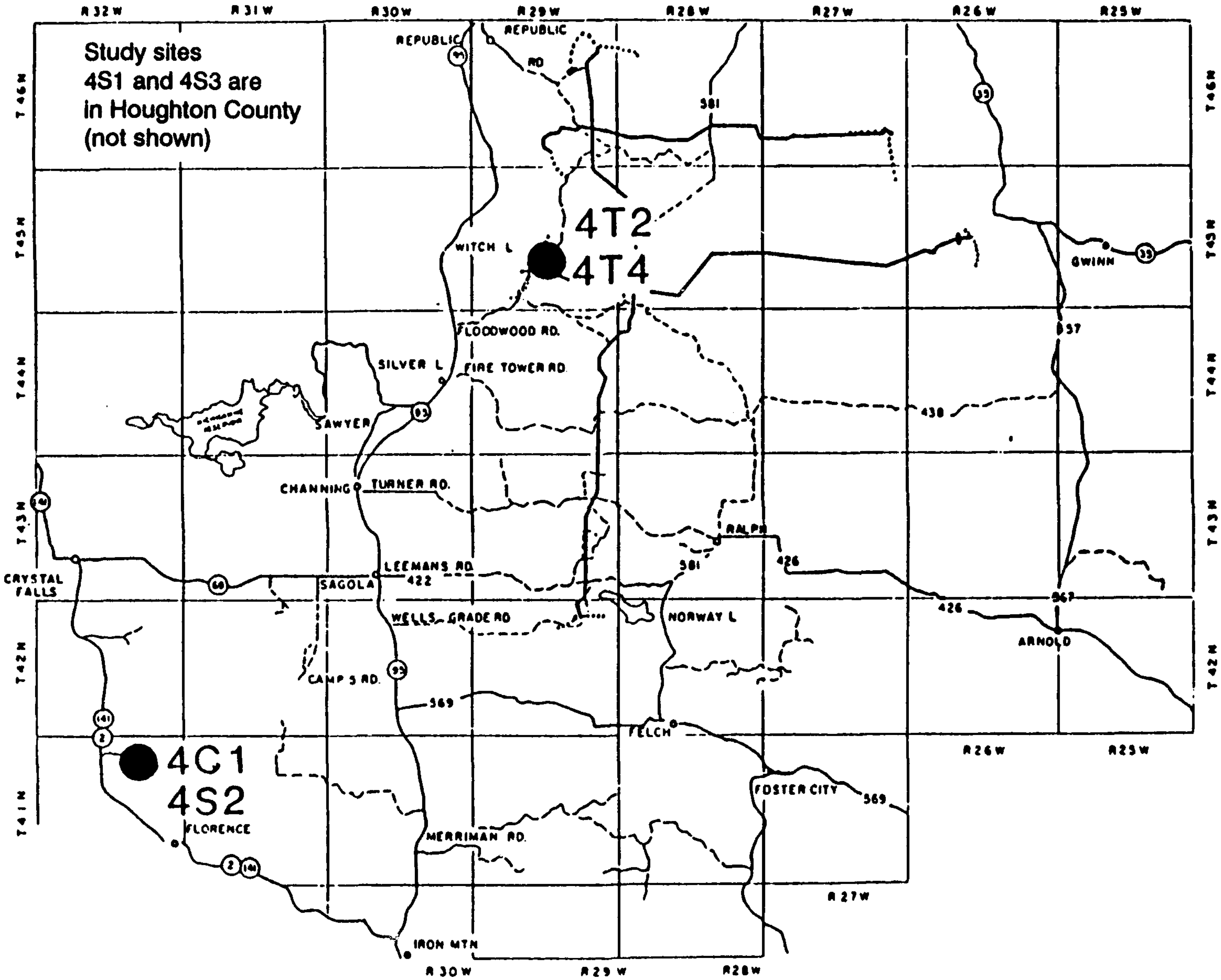


FIGURE D-1. POSITIONS OF UPLAND FLORA AND SOIL MICROFLORA STUDY SITES RELATIVE TO NRTF-REPUBLIC ANTENNA ELEMENTS.

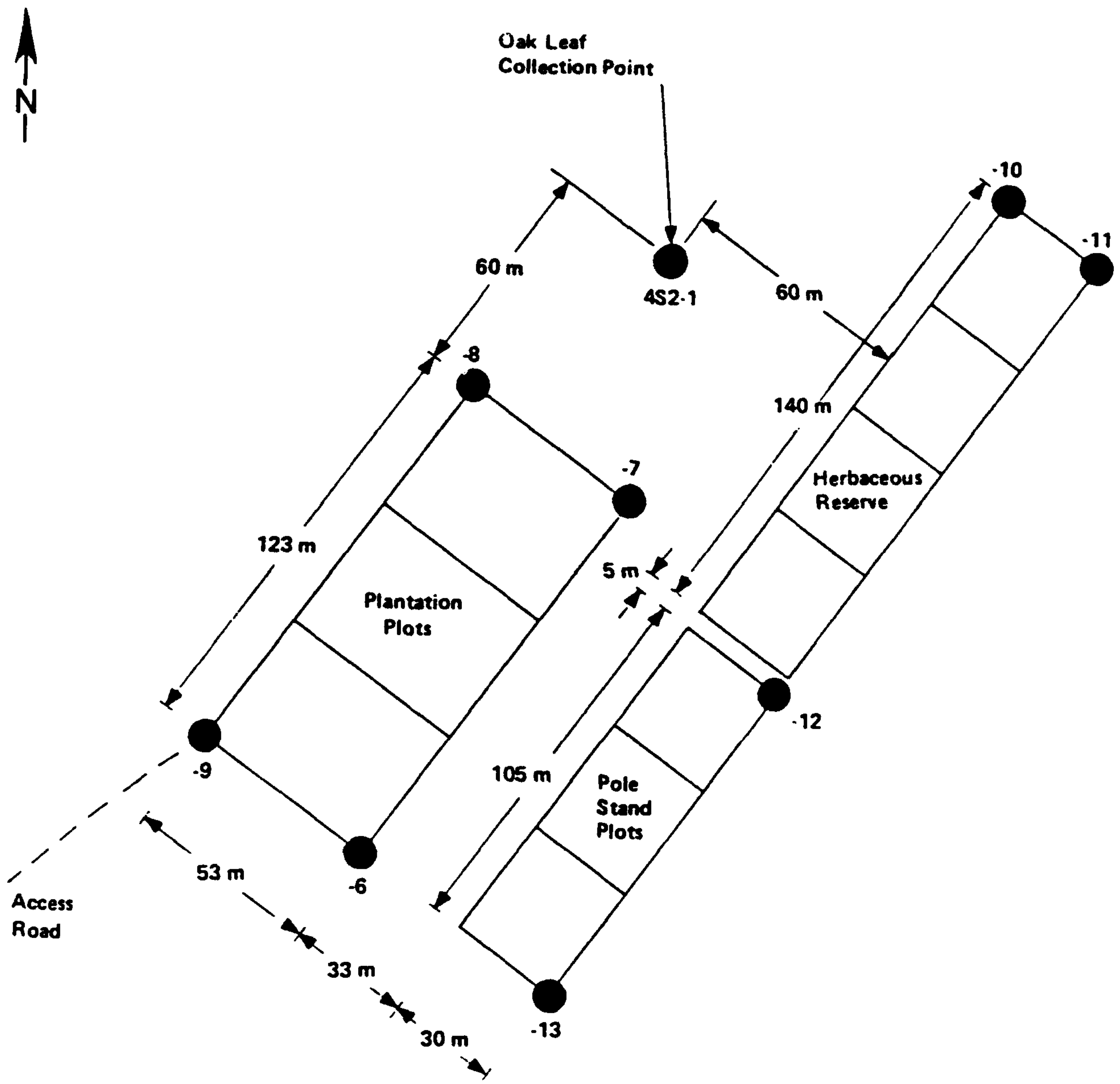


FIGURE D-2. MEASUREMENT POINTS AT PAINT POND ROAD CONTROL; 4C1-6 THROUGH 13, AND OAK LEAF COLLECTION SITE; 4S2-1.

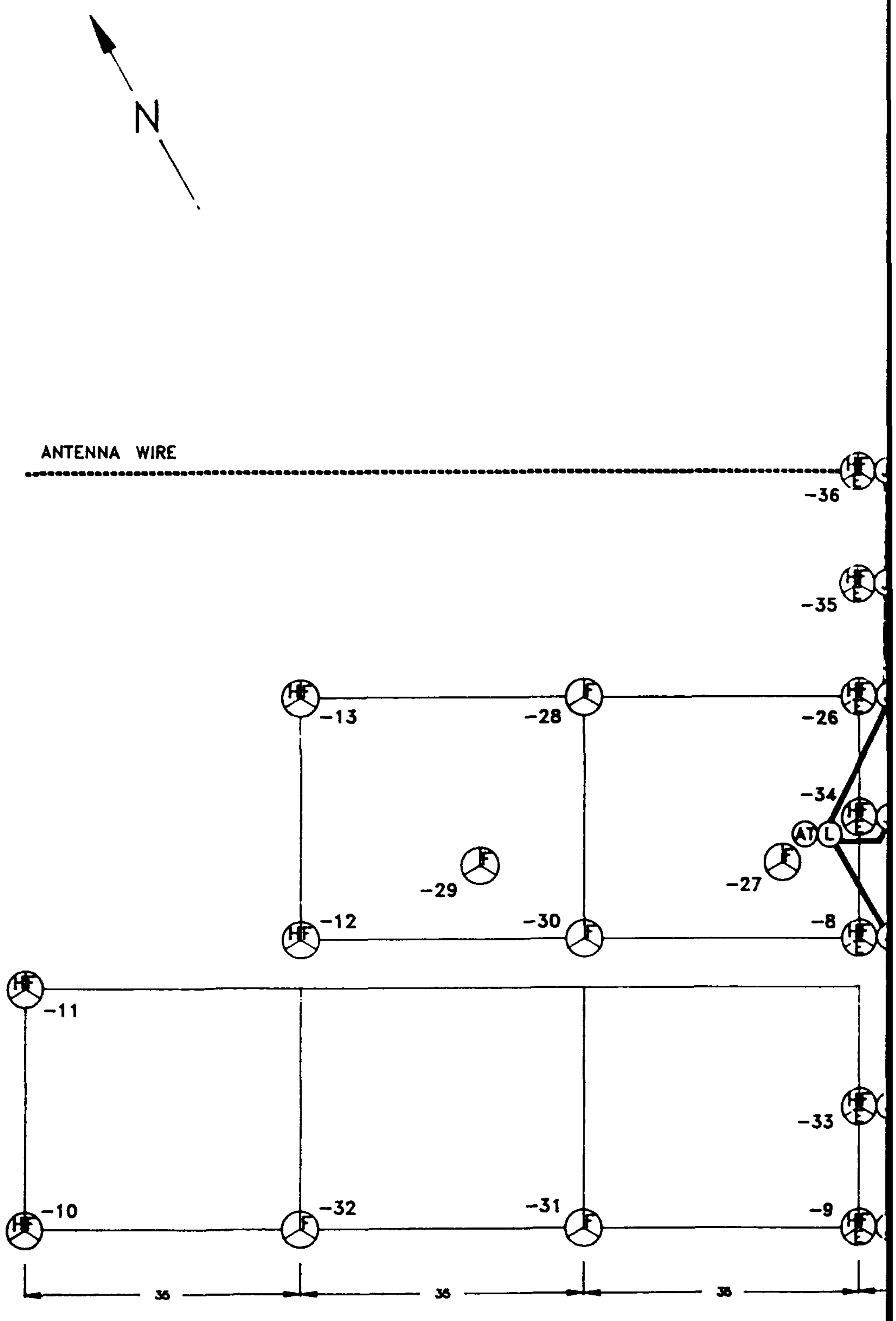


FIGURE D-3. HISTORIC AND FIXED M
ML; 4T2-3 THROUGH 19.

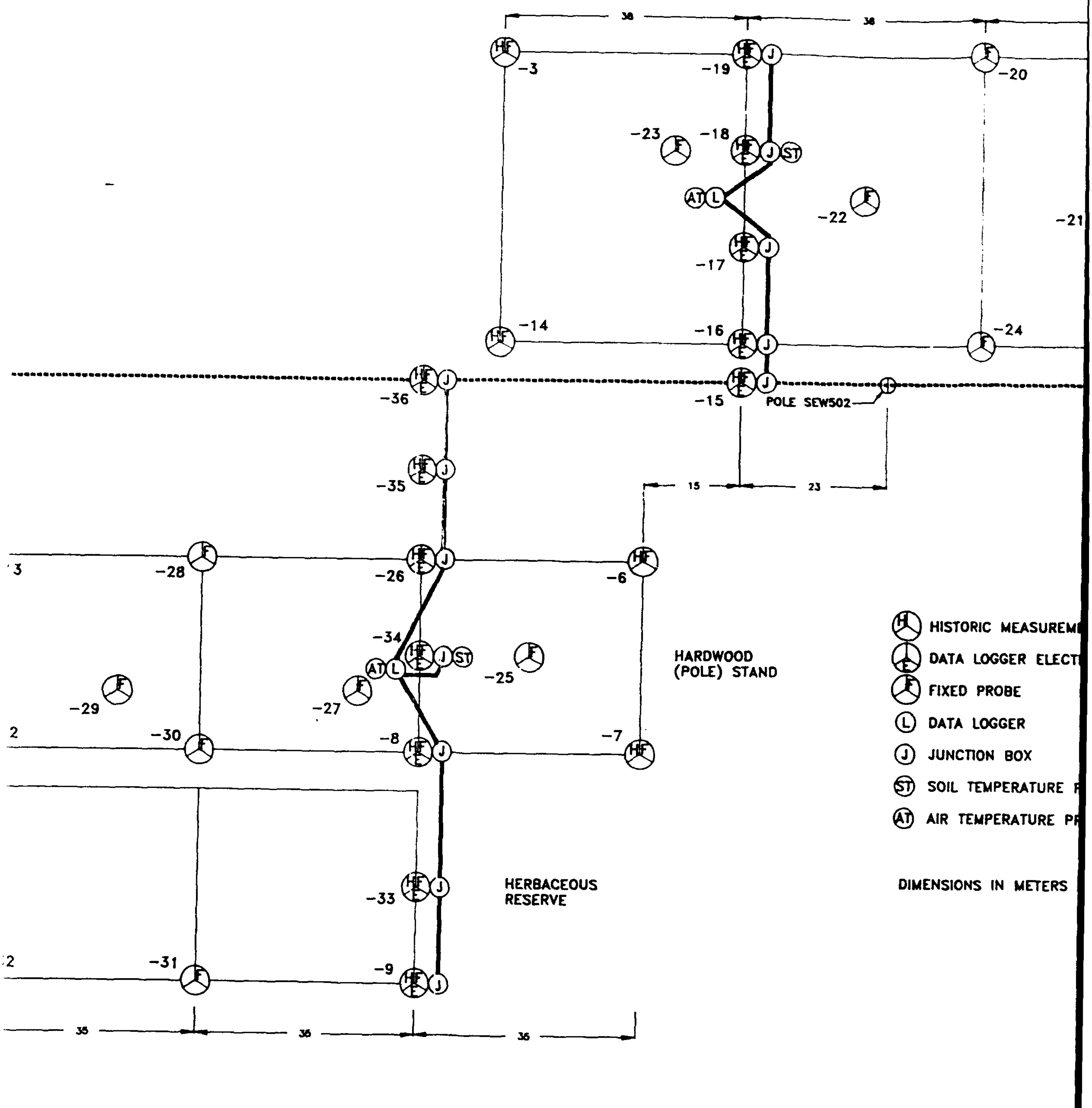
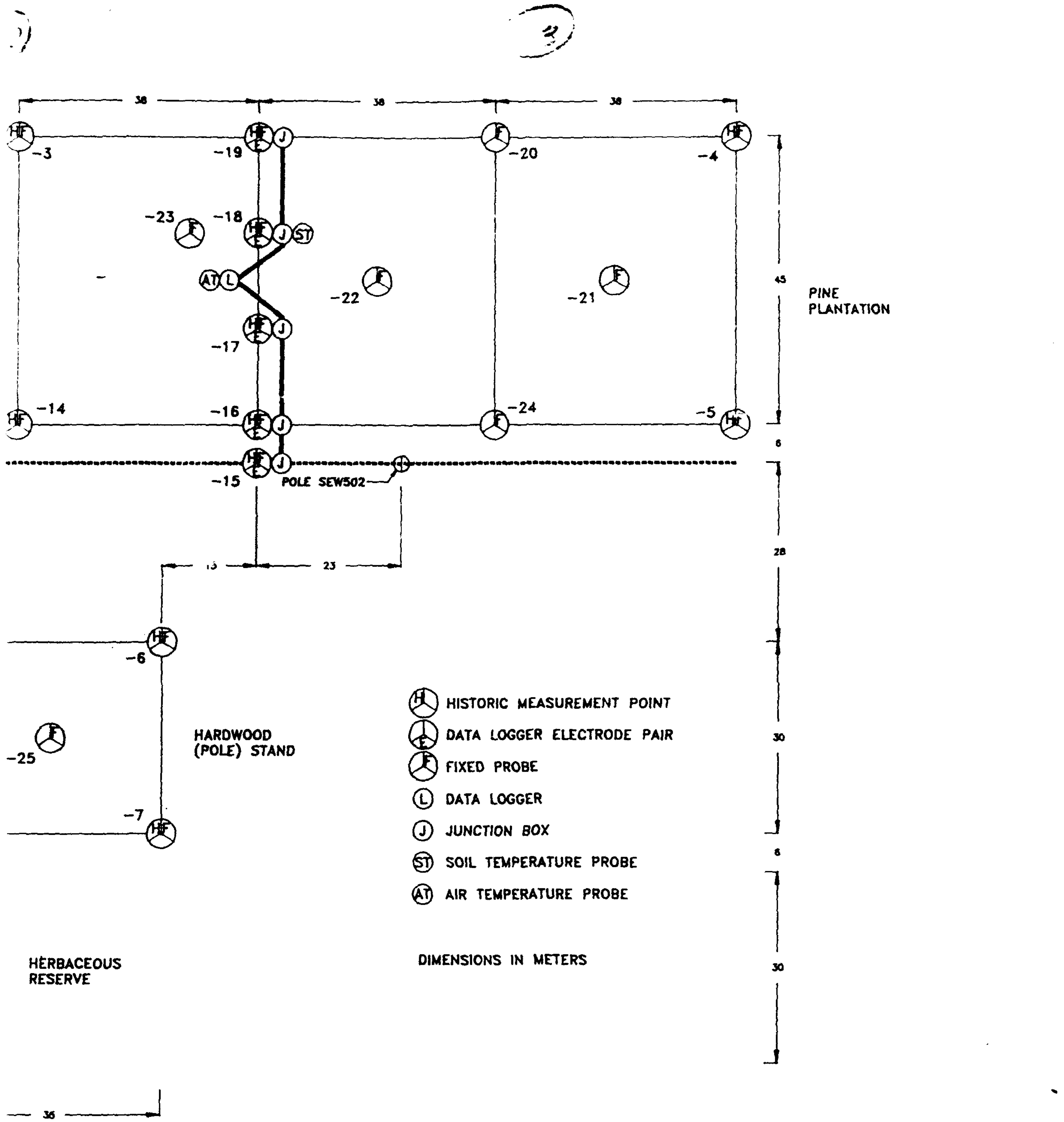


FIGURE D-3. HISTORIC AND FIXED MEASUREMENT POINTS AT MARTELL'S LAKE (OVERHEAD): ML; 4T2-3 THROUGH 19.



REMENT POINTS AT MARTELL'S LAKE (OVERHEAD):

IITRI D06200-4

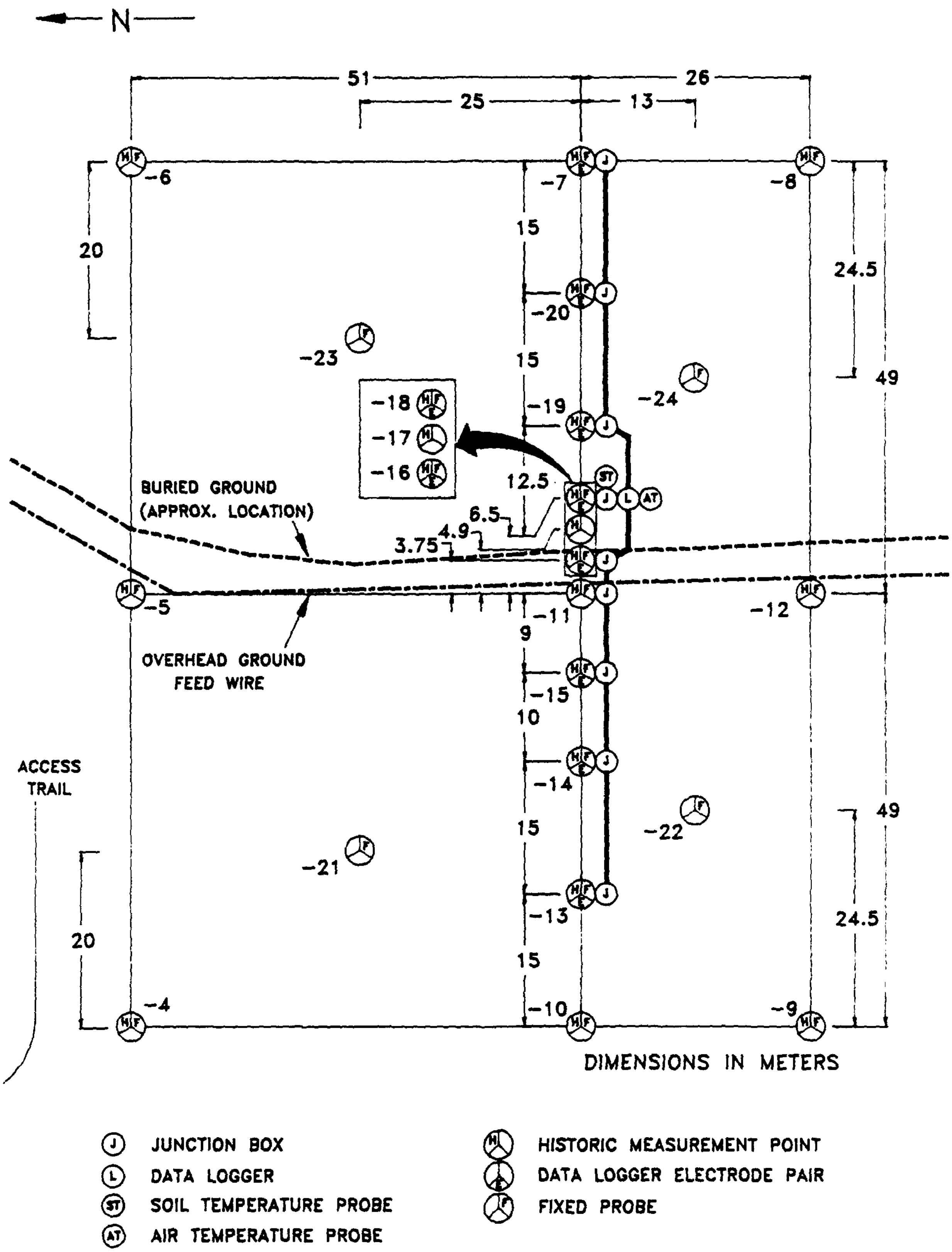


FIGURE D-4. HISTORIC AND FIXED MEASUREMENT POINTS AT MARTELL'S LAKE (BURIED): EP; 4T4-4 THROUGH 24.

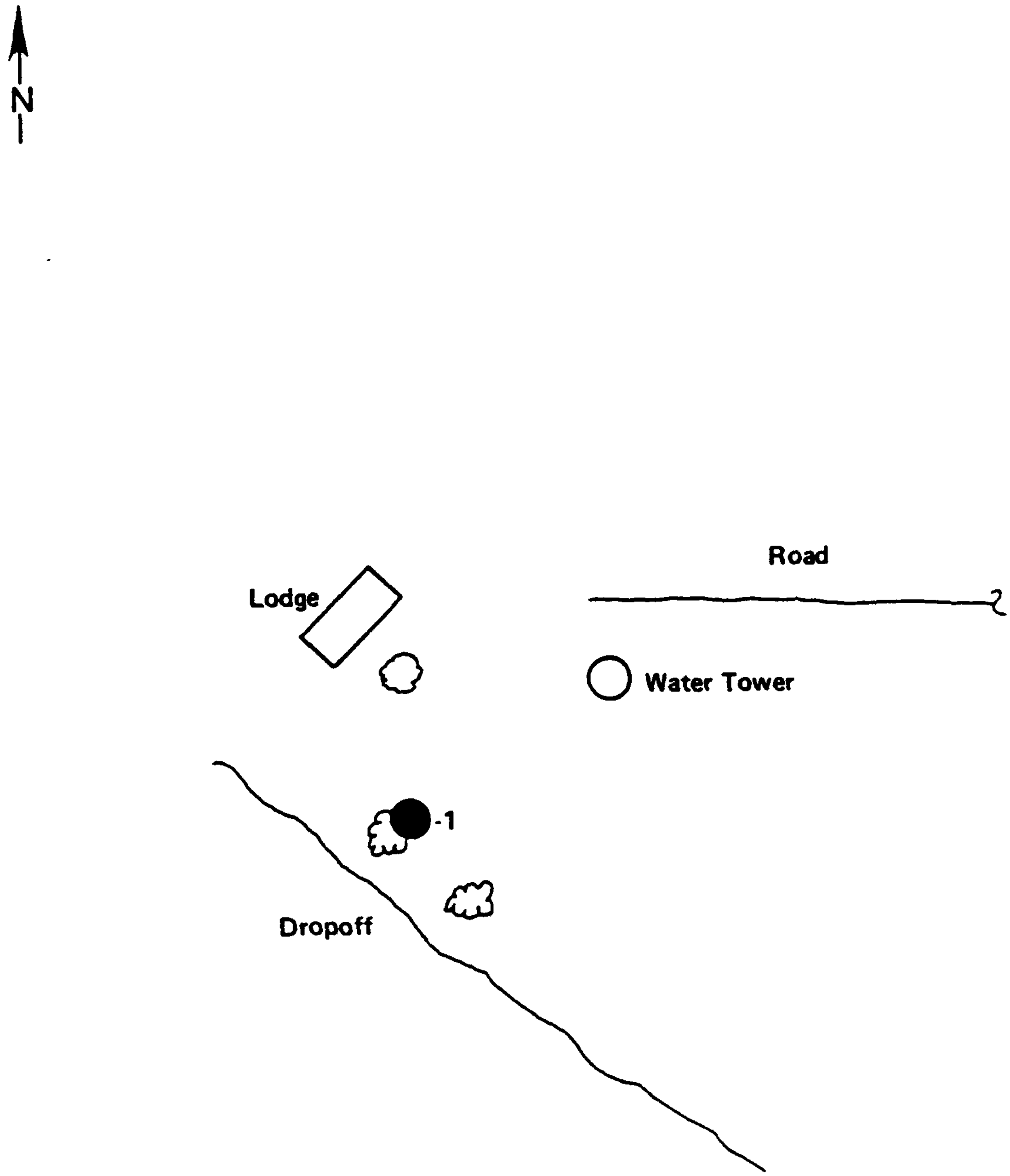


FIGURE D-5. MEASUREMENT POINT AT RED MAPLE LEAF COLLECTION SITE; 4S1-1.

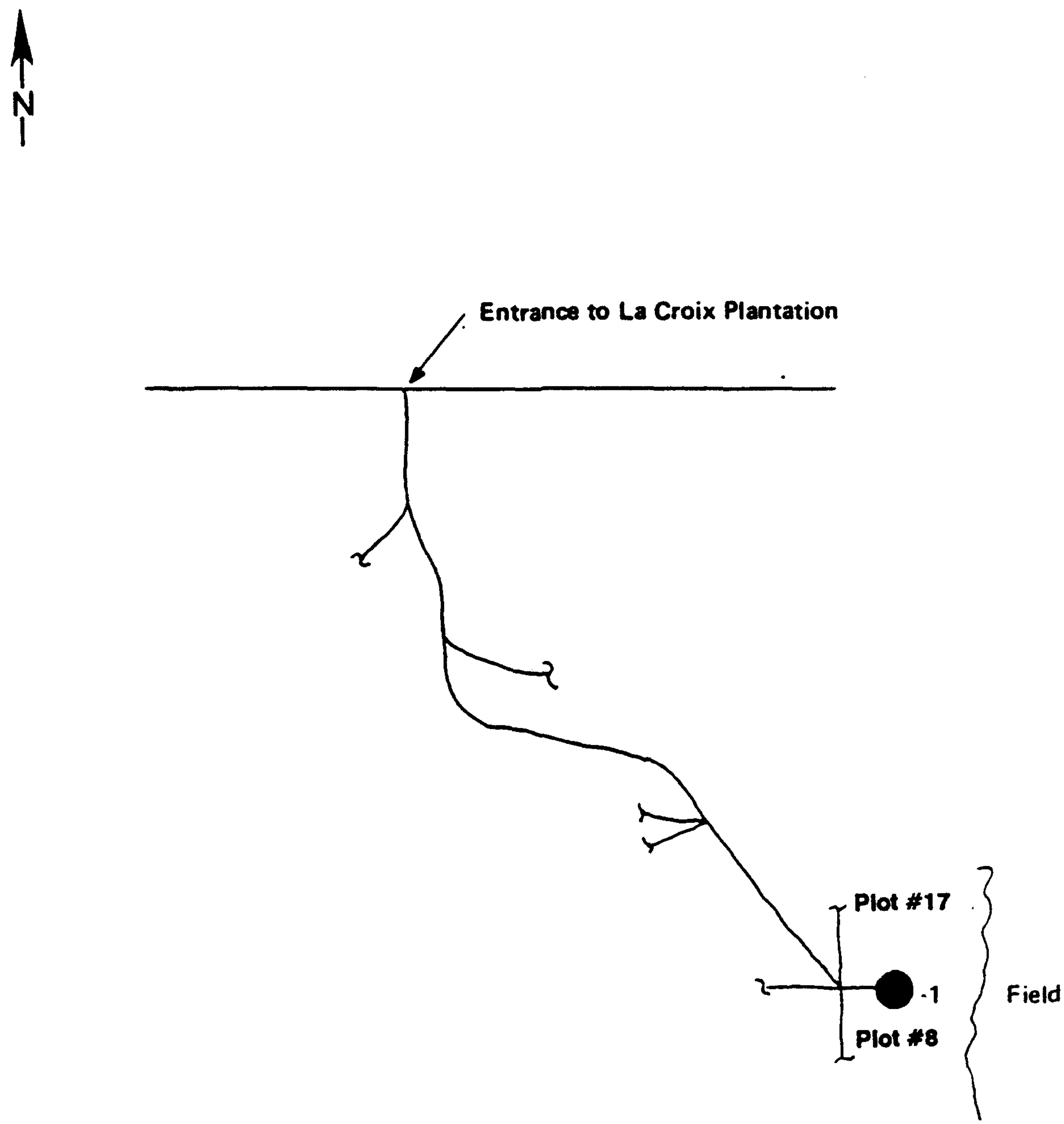


FIGURE D-6. MEASUREMENT POINT AT THE PINE NEEDLE COLLECTION SITE; 4S3-1.

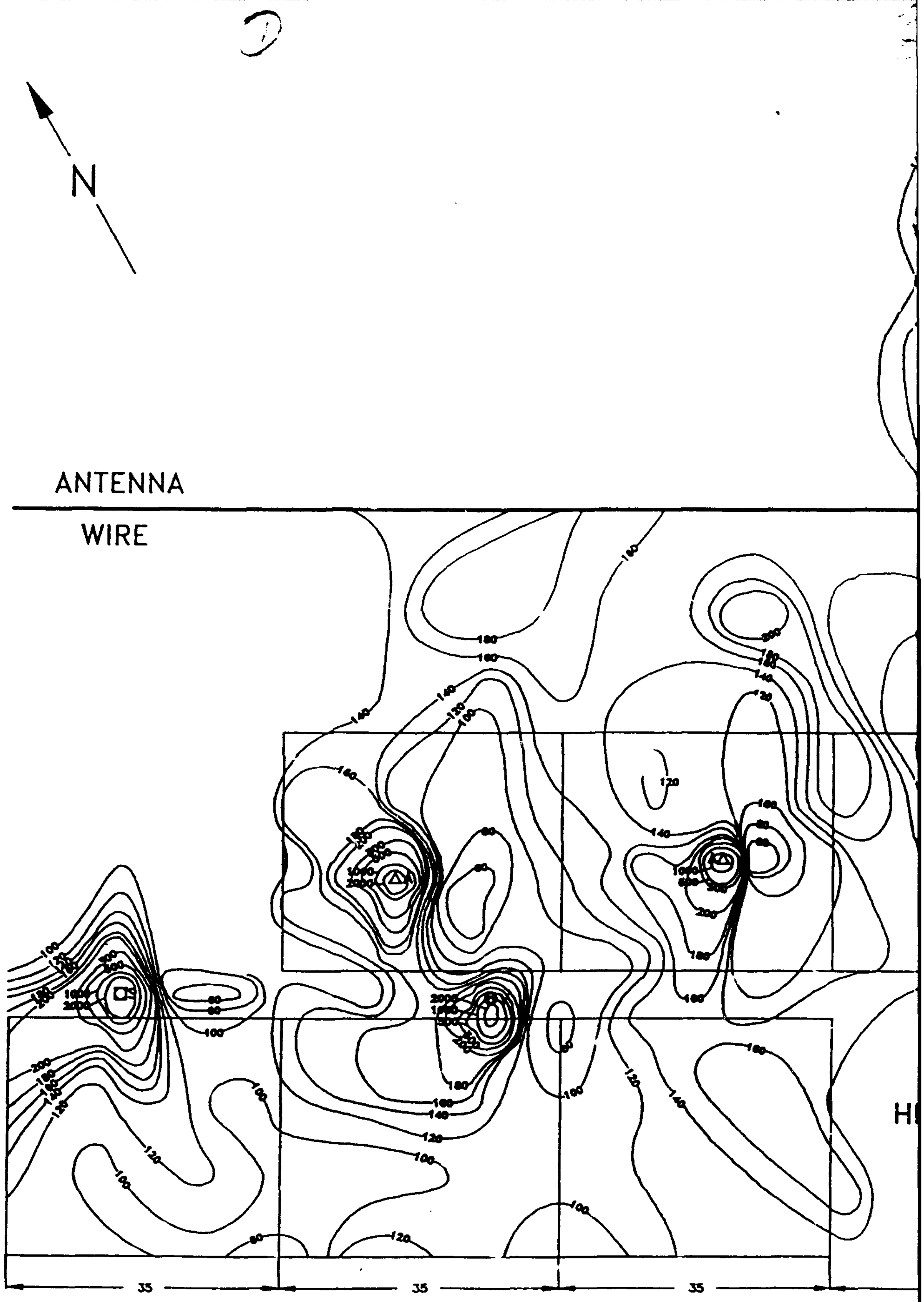


FIGURE D-7. EARTH ELECTRIC FIELD CON
ML; JUNE 1990.

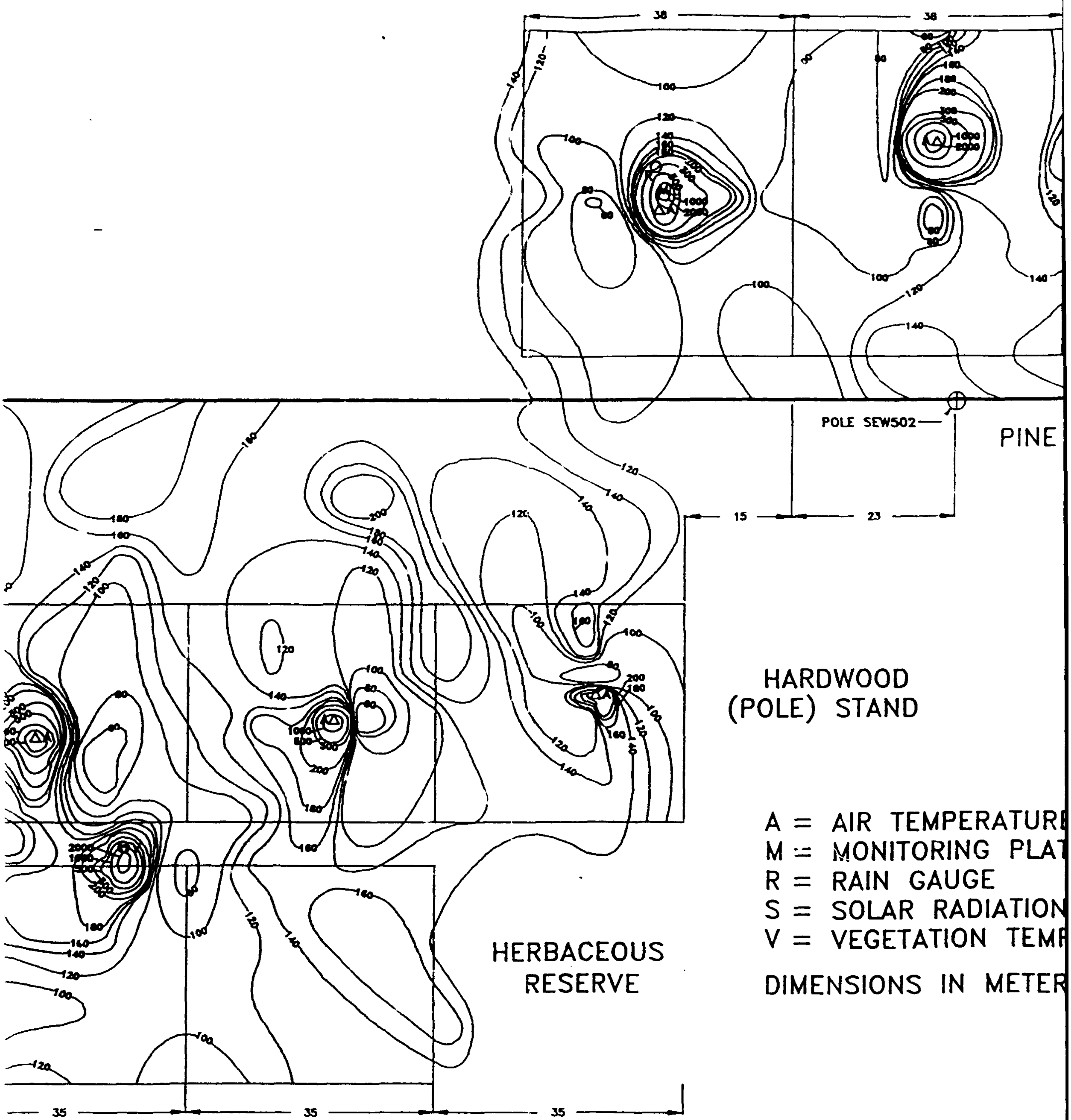
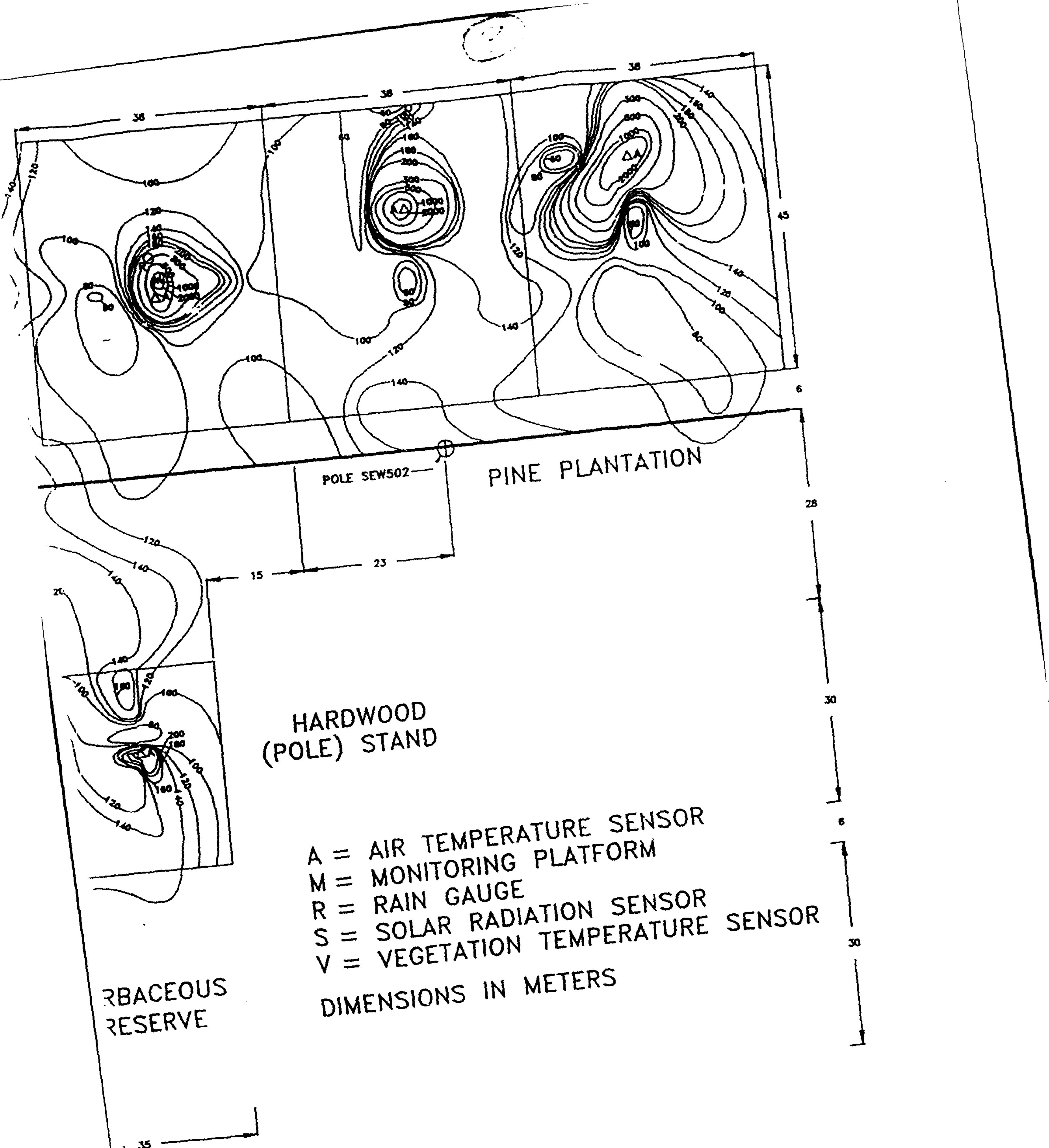


FIGURE D-7. EARTH ELECTRIC FIELD CONTOURS (mV/m), MARTELL'S LAKE (OVERHEAD): ML; JUNE 1990.



URS (mV/m), MARTELL'S LAKE (OVERHEAD):

IITRI D06200-4

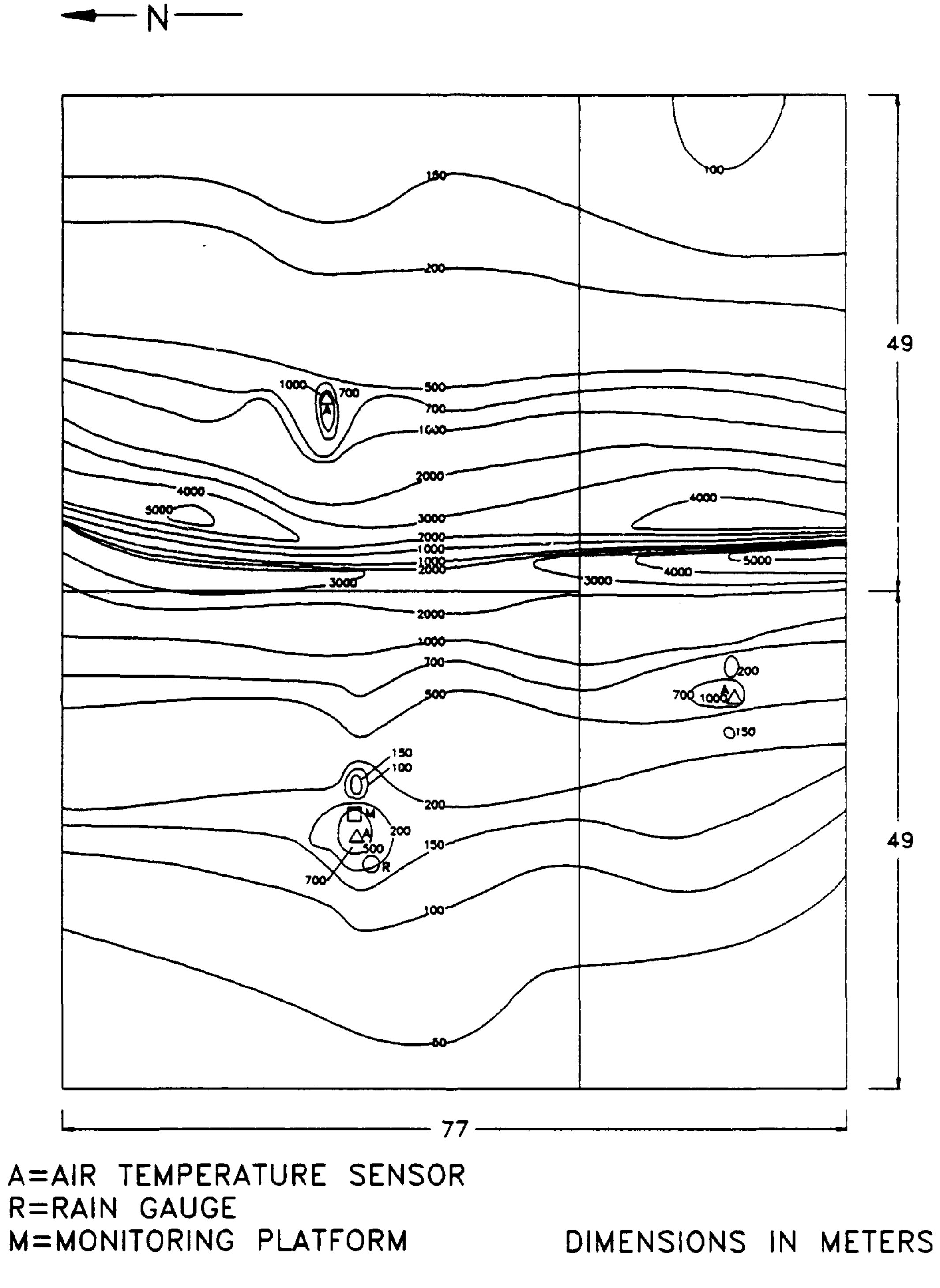


FIGURE D-8. EARTH ELECTRIC FIELD CONTOURS (mV/m), MARTELL'S LAKE (BURIED): EP; JUNE 1990.

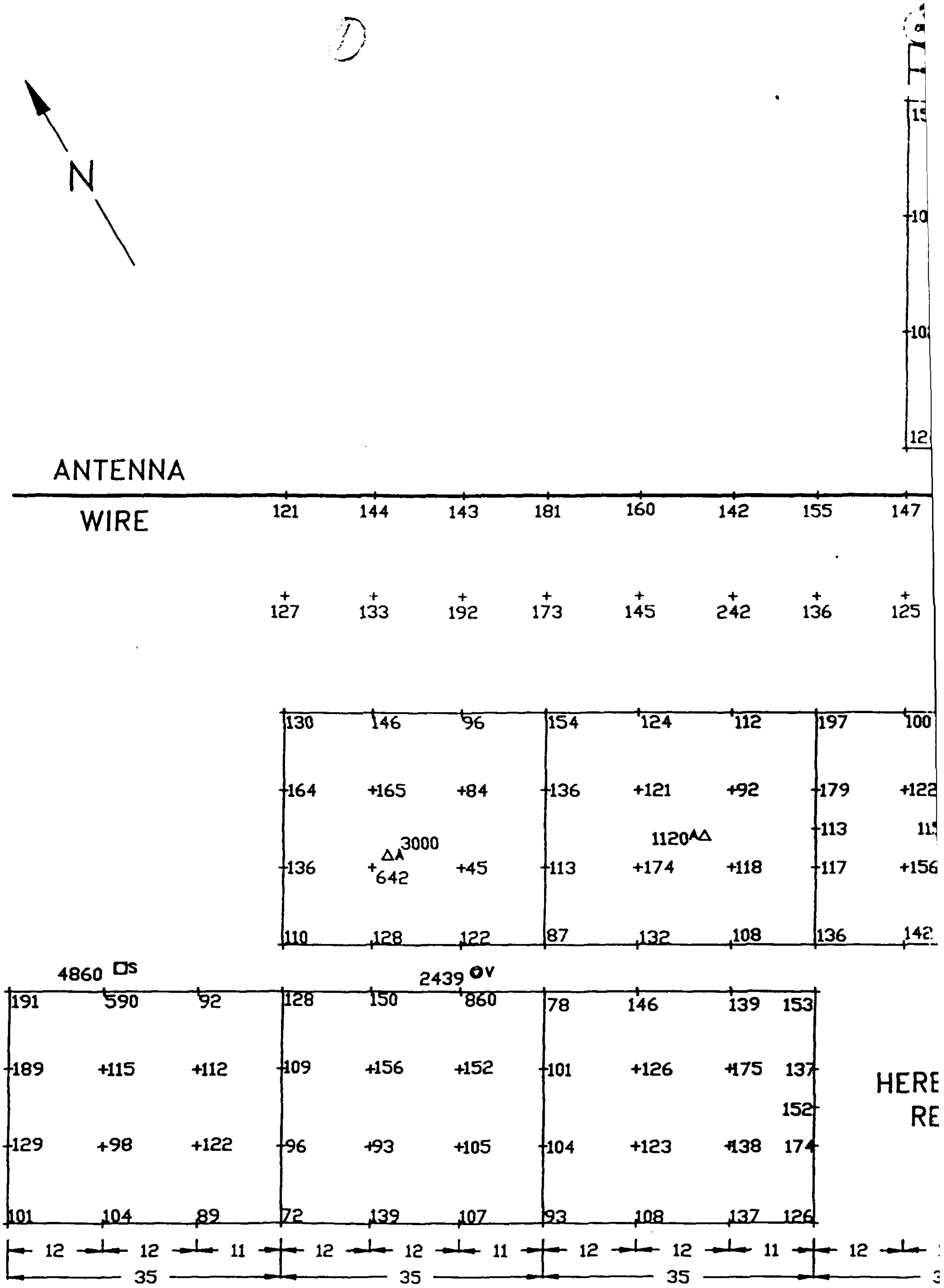


FIGURE D-9. EARTH ELECTRIC FIELD SUR
ML; JUNE 1990.

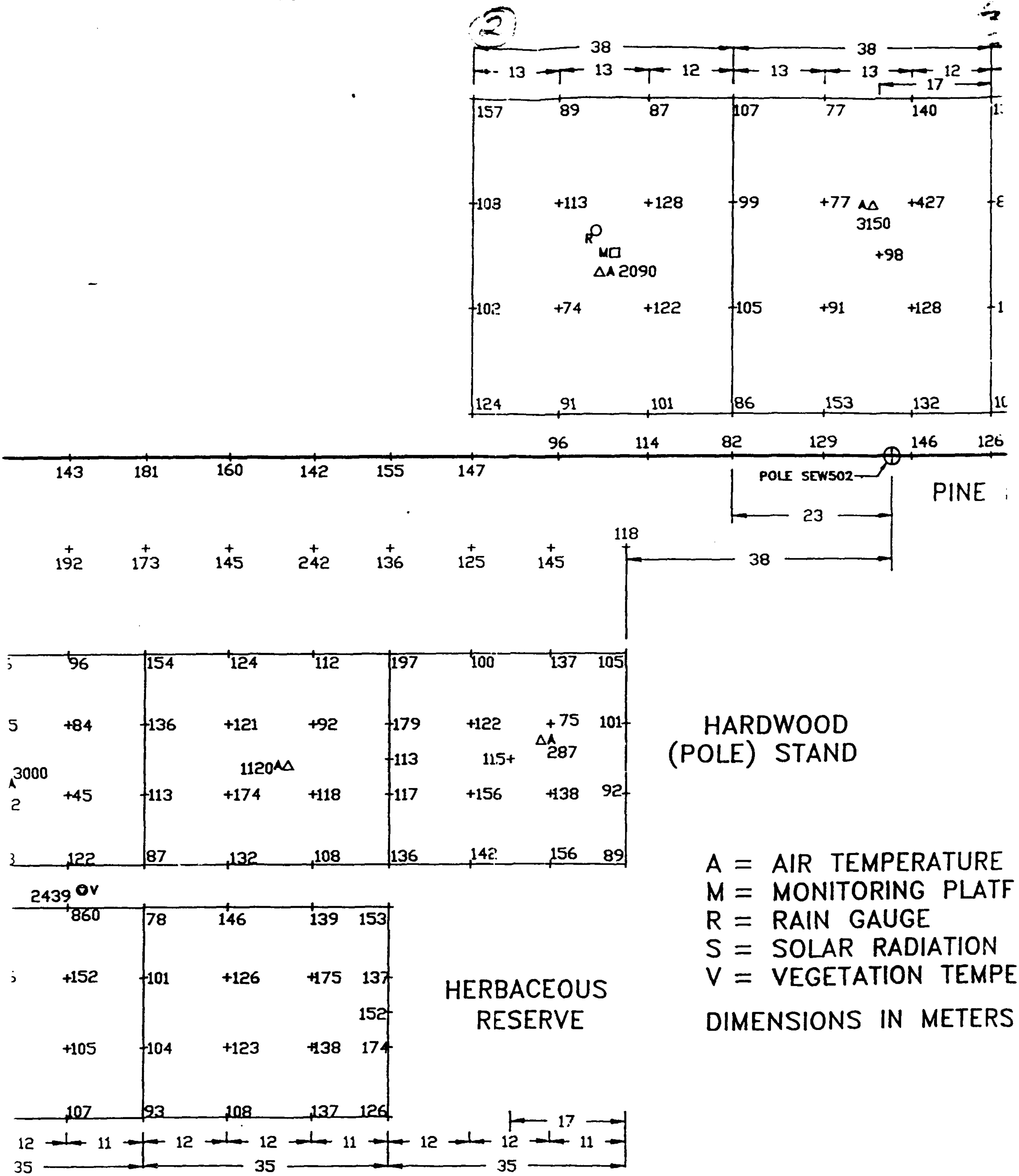
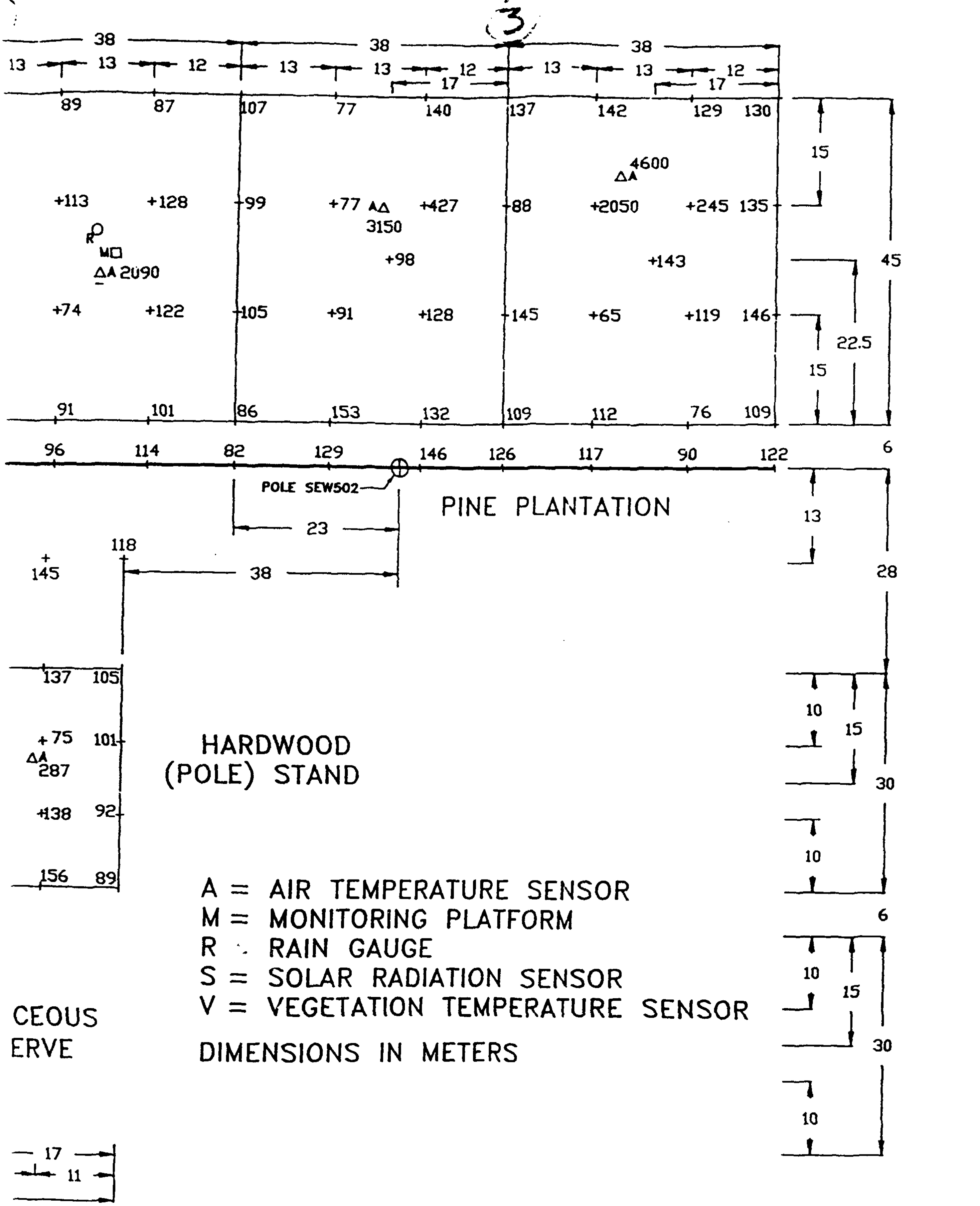
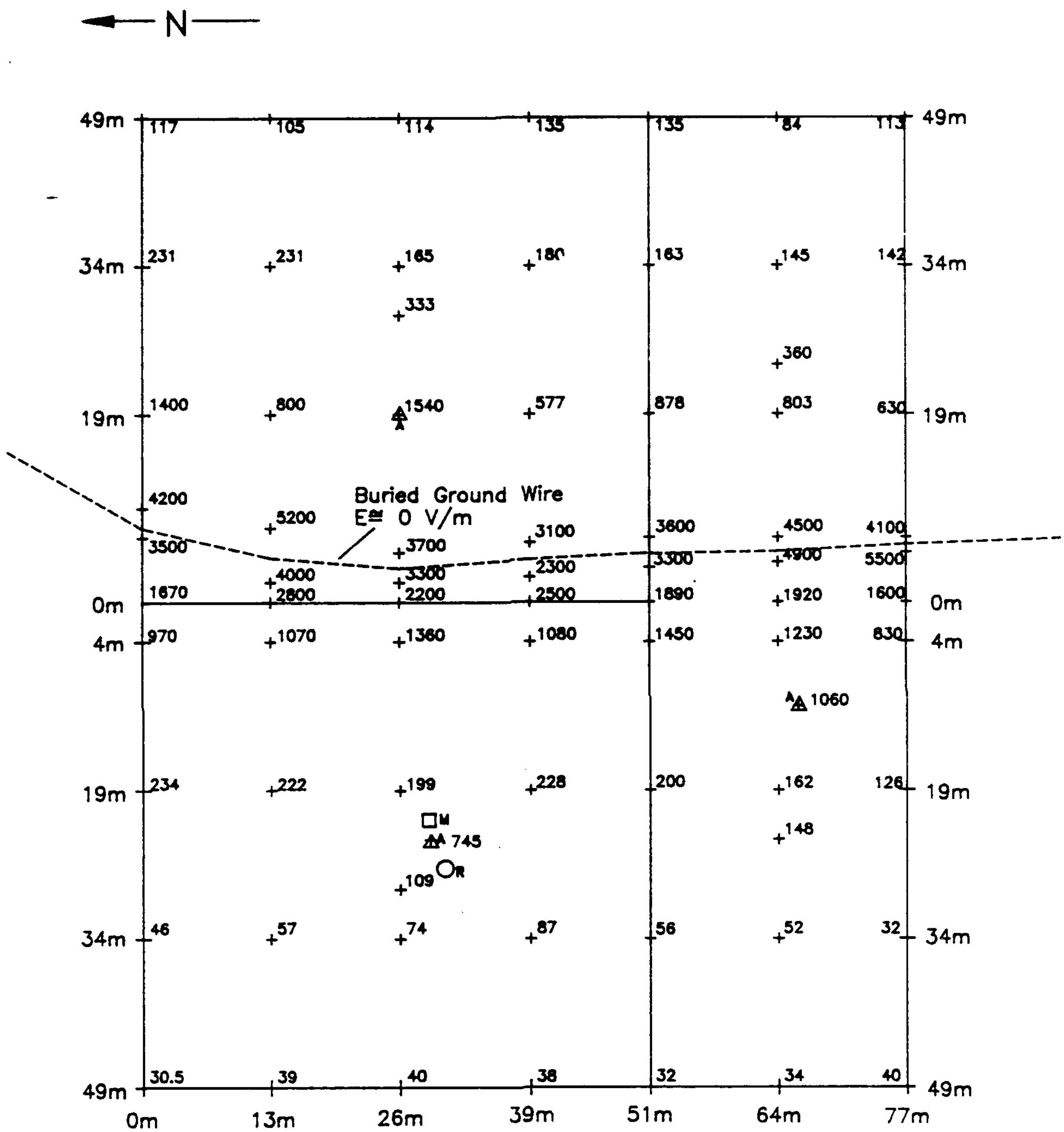


FIGURE D-9. EARTH ELECTRIC FIELD SURVEY (mV/m), MARTELL'S LAKE (OVERHEAD): ML; JUNE 1990.



/ (mV/m), MARTELL'S LAKE (OVERHEAD):

IITRI D06200-4



A=AIR TEMPERATURE SENSOR
R=RAIN GAUGE
M=MONITORING PLATFORM

DIMENSIONS IN METERS

FIGURE D-10. EARTH ELECTRIC FIELD S''RVEY (mV/m), MARTELL'S LAKE (BURIED: EP; JUNE 1990.

TABLE D-3. 60 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Upland Flora and Soil Microflora Studies
(page 1 of 2)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989	1990	1991
4C1-6	-	0.003	<	<	<	<	<[d]	<[b]	<[d]
4C1-7	-	0.006	<	<	<	<	<[d]	<[b]	<[d]
4C1-8	-	0.004	<	<	<	<	<[d]	<[b]	<[d]
4C1-9	-	0.002	<	<	<	<	<[d]	<[b]	<[d]
4C1-10	-	-	<	<	<	<	<[d]	<[b]	<[d]
4C1-11	-	-	<	<	<	<	<[d]	<[b]	<[d]
4C1-12	-	-	<	<	<	<	<[d]	<[b]	<[d]
4C1-13	-	-	<	<	<	<	<[d]	<[b]	<[d]
4T2-3	-	0.001	<	<	<	0.002	#[d]	#[d]	/
4T2-4	-	-	<	<	<	0.001	#[d]	#[d]	/
4T2-5	-	-	<	<	<	0.011	#[d]	#[d]	/
4T2-6	-	-	<	<	<	<0.001	#[d]	#[d]	/
4T2-7	-	-	<	<	<	<0.001	#[d]	#[d]	/
4T2-8	-	-	<	<	<	/	#[d]	#[d]	/
4T2-9	-	-	<	<	<	<	#[d]	#[d]	/
4T2-10	-	-	<	<	<	<	#[d]	#[d]	/
4T2-11	-	-	<	<	<	<	#[d]	#[d]	/
4T2-12	-	-	<	<	<	/	#[d]	#[d]	/
4T2-13	-	-	<	<	<	<0.001	#[d]	#[d]	/
4T2-14	-	-	<	<	<	0.011	#[d]	#[d]	/
4T2-15	-	-	-	-	-	-	#[d]	#[d]	/
4T2-16	-	-	-	-	-	-	#[d]	#[d]	/
4T2-17	-	-	-	-	-	-	#[d]	#[d]	/
4T2-18	-	-	-	-	-	-	#[d]	#[d]	/
4T2-19	-	-	-	-	-	-	#[d]	#[d]	/
4T2-26	-	-	-	-	-	-	-	#[d]	/
4T2-33	-	-	-	-	-	-	-	#[d]	/
4T2-34	-	-	-	-	-	-	-	#[d]	/
4T2-35	-	-	-	-	-	-	-	#[d]	/
4T2-36	-	-	-	-	-	-	-	#[d]	/

TABLE D-3. 60 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Upland Flora and Soil Microflora Studies
(page 2 of 2)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989	1990	1991
4T4-4	-	0.003	<	<	<0.001	<0.001	#[d]	#[d]	/
4T4-5	-	-	<	<	0.006	0.003	#[d]	#[d]	/
4T4-6	-	-	<	<	<	<	#[d]	#[d]	/
4T4-7	-	-	<	<	<	<	#[d]	#[d]	/
4T4-8	-	-	<	<	<	<	#[d]	#[d]	/
4T4-9	-	-	<	<	<	<	#[d]	#[d]	/
4T4-10	-	-	<	<	<	<	#[d]	#[d]	/
4T4-11	-	-	<	<	0.010	0.009	#[d]	#[d]	/
4T4-12	-	-	-	<	0.005	0.007	#[d]	#[d]	/
4T4-13	-	-	-	-	-	-	#[d]	#[d]	/
4T4-14	-	-	-	-	-	-	#[d]	#[d]	/
4T4-15	-	-	-	-	-	-	#[d]	#[d]	/
4T4-16	-	-	-	-	-	-	#[d]	#[d]	/
4T4-17	-	-	-	-	-	-	#[d]	#[d]	/
4T4-18	-	-	-	-	-	-	#[d]	#[d]	/
4T4-19	-	-	-	-	-	-	#[d]	#[d]	/
4T4-20	-	-	-	-	-	-	#[d]	#[d]	/
4S1-1	-	-	-	-	0.013	0.033	0.011[b]	0.017[b]	0.018[b]
4S2-1	-	-	-	-	<	<	<[d]	<[b]	<[d]
4S3-1	-	-	-	-	<0.001	<0.001	<0.001[b]	<0.001[b]	/

a = antennas not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 A current.

\- = measurement point not established.
/ = measurement not taken.
= measurement precluded by antenna operation.
< = measurement est. <0.001 V/m based on earth E-field.

TABLE D-4. 60 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Studies
(page 1 of 2)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989	1990	1991
4C1-6	-	0.022	0.016	0.005	0.043	0.023	0.016[d]	0.024[b]	0.012[d]
4C1-7	-	0.143	0.123	0.077	0.178	0.118	0.030[d]	0.039[b]	0.043[d]
4C1-8	-	0.104	0.117	0.077	0.131	0.078	0.018[d]	0.063[b]	0.020[d]
4C1-9	-	0.011	0.019	0.024	0.034	0.032	0.023[d]	0.023[b]	0.018[d]
4C1-10	-	-	0.090	0.068	0.118	0.106	0.054[d]	0.041[b]	0.030[d]
4C1-11	-	-	0.160	0.107	0.132	0.146	0.066[d]	0.068[b]	0.048[d]
4C1-12	-	-	0.104	0.101	0.075	0.093	0.042[d]	0.042[b]	0.033[d]
4C1-13	-	-	0.040	0.030	0.046	0.065	0.025[d]	0.039[b]	0.014[d]
4T2-3	-	0.51	0.39	0.194	0.27	0.28	#[d]	#[d]	0.52[b]
4T2-4	-	-	0.27	0.24	0.30	0.25	#[d]	#[d]	0.59[b]
4T2-5	-	-	0.43	0.32	0.20	0.20	#[d]	#[d]	0.77[b]
4T2-6	-	-	0.66	0.46	0.192	0.22	#[d]	#[d]	0.84[b]
4T2-7	-	-	0.42	0.52	0.197	0.28	#[d]	#[d]	0.71[b]
4T2-8	-	-	0.47	0.190	0.22	/	#[d]	#[d]	0.79[b]
4T2-9	-	-	0.49	0.31	0.183	0.25	#[d]	#[d]	0.62[b]
4T2-10	-	-	0.44	0.32	0.155	0.166	#[d]	#[d]	0.71[b]
4T2-11	-	-	0.51	0.40	0.31	0.43	#[d]	#[d]	0.72[b]
4T2-12	-	-	0.47	0.38	0.24	/	#[d]	#[d]	0.73[b]
4T2-13	-	-	0.76	0.31	0.31	0.25	#[d]	#[d]	0.87[b]
4T2-14	-	-	0.61	0.29	0.35	0.21	#[d]	#[d]	0.78[b]
4T2-15	-	-	-	-	-	-	#[d]	#[d]	1.01[b]
4T2-16	-	-	-	-	-	-	#[d]	#[d]	0.66[b]
4T2-17	-	-	-	-	-	-	#[d]	#[d]	0.93[b]
4T2-18	-	-	-	-	-	-	#[d]	#[d]	0.73[b]
4T2-19	-	-	-	-	-	-	#[d]	#[d]	0.64[b]
4T2-26	-	-	-	-	-	-	-	#[d]	0.61[b]
4T2-33	-	-	-	-	-	-	-	#[d]	0.75[b]
4T2-34	-	-	-	-	-	-	-	#[d]	0.81[b]
4T2-35	-	-	-	-	-	-	-	#[d]	0.73[b]
4T2-36	-	-	-	-	-	-	-	#[d]	0.60[b]

TABLE D-4. 60 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Studies
(page 2 of 2)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989	1990	1991
4T4-4	-	0.72	0.42	0.185	0.56	0.079	#[d]	#[d]	0.40[b]
4T4-5	-	-	0.58	0.58	4.3	1.12	#[d]	#[d]	3.1[b]
4T4-6	-	-	0.22	0.16	0.61	0.188	#[d]	#[d]	0.35[b]
4T4-7	-	-	0.44	0.29	0.64	0.22	#[d]	#[d]	0.28[b]
4T4-8	-	-	0.42	0.193	0.40	0.23	#[d]	#[d]	0.27[b]
4T4-9	-	-	0.50	0.21	0.27	0.073	#[d]	#[d]	0.31[b]
4T4-10	-	-	0.42	0.22	0.29	0.063	#[d]	#[d]	0.23[b]
4T4-11	-	-	0.40	0.60	2.7	1.27	#[d]	#[d]	4.1[b]
4T4-12	-	-	-	0.75	3.4	1.35	#[d]	#[d]	0.34[b]
4T4-13	-	-	-	-	-	-	#[d]	#[d]	0.22[b]
4T4-14	-	-	-	-	-	-	#[d]	#[d]	0.53[b]
4T4-15	-	-	-	-	-	-	#[d]	#[d]	1.29[b]
4T4-16	-	-	-	-	-	-	#[d]	#[d]	4.4[b]
4T4-17	-	-	-	-	-	-	#[d]	#[d]	/
4T4-18	-	-	-	-	-	-	#[d]	#[d]	4.6[b]
4T4-19	-	-	-	-	-	-	#[d]	#[d]	1.17[b]
4T4-20	-	-	-	-	-	-	#[d]	#[d]	0.27[b]
4S1-1	-	-	-	-	8.5	12.2	11.6[b]	15.7[b]	9.1[b]
4S2-1	-	-	-	-	0.155	0.109	0.032[d]	0.068[b]	0.060[d]
4S3-1	-	-	-	-	0.65	1.73	0.73[b]	0.87[b]	0.69[b]

a = antennas not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 A current.

\- = measurement point not established.
/ = measurement not taken.
= measurement precluded by antenna operation.

TABLE D-5. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Upland Flora and Soil Microflora Studies
(page 1 of 2)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989	1990	1991
4C1-6	-	0.003	0.003	0.003	0.002	0.003	0.002[d]	0.002[b]	0.001[d]
4C1-7	-	0.003	0.002	0.001	0.003	0.002	0.001[d]	0.002[b]	0.001[d]
4C1-8	-	0.003	0.003	0.002	0.003	0.002	0.001[d]	0.002[b]	0.002[d]
4C1-9	-	0.003	0.003	0.002	0.001	0.002	0.002[d]	0.002[b]	0.001[d]
4C1-10	-	-	0.002	0.002	0.002	0.002	0.002[d]	0.002[b]	0.001[d]
4C1-11	-	-	0.002	0.002	0.002	0.002	0.001[d]	0.002[b]	0.001[d]
4C1-12	-	-	0.002	0.003	0.001	0.002	0.001[d]	0.002[b]	0.001[d]
4C1-13	-	-	0.002	0.003	0.001	0.003	0.002[d]	0.002[b]	0.001[d]
4T2-3	-	0.002	0.001	0.001	0.003	0.005	#[d]	#[d]	0.004[b]
4T2-4	-	-	0.001	0.001	0.003	0.006	#[d]	#[d]	0.005[b]
4T2-5	-	-	0.001	0.007	0.017	0.030	#[d]	#[d]	0.029[b]
4T2-6	-	-	0.001	0.006	0.006	0.014	#[d]	#[d]	0.017[b]
4T2-7	-	-	0.001	0.004	0.004	0.007	#[d]	#[d]	0.010[b]
4T2-8	-	-	0.001	0.002	0.004	/	#[d]	#[d]	0.010[b]
4T2-9	-	-	0.001	0.003	0.003	0.005	#[d]	#[d]	0.007[b]
4T2-10	-	-	0.001	0.003	0.003	0.005	#[d]	#[d]	0.007[b]
4T2-11	-	-	0.001	0.004	0.005	0.007	#[d]	#[d]	0.009[b]
4T2-12	-	-	0.002	0.004	0.005	/	#[d]	#[d]	0.010[b]
4T2-13	-	-	0.001	0.005	0.008	0.013	#[d]	#[d]	0.016[b]
4T2-14	-	-	0.002	0.011	0.018	0.029	#[d]	#[d]	0.035[b]
4T2-15	-	-	-	-	-	-	#[d]	#[d]	0.043[b]
4T2-16	-	-	-	-	-	-	#[d]	#[d]	0.033[b]
4T2-17	-	-	-	-	-	-	#[d]	#[d]	0.016[b]
4T2-18	-	-	-	-	-	-	#[d]	#[d]	0.009[b]
4T2-19	-	-	-	-	-	-	#[d]	#[d]	0.004[b]
4T2-26	-	-	-	-	-	-	-	#[d]	0.015[b]
4T2-33	-	-	-	-	-	-	-	#[d]	0.008[b]
4T2-34	-	-	-	-	-	-	-	#[d]	0.012[b]
4T2-35	-	-	-	-	-	-	-	#[d]	0.030[b]
4T2-36	-	-	-	-	-	-	-	#[d]	0.042[b]

TABLE D-5. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Upland Flora and Soil Microflora Studies
(page 2 of 2)

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989	1990	1991
4T4-4	-	0.004	0.002	0.001	0.003	0.003	#[d]	#[d]	0.003[b]
4T4-5	-	-	0.002	0.006	0.010	0.017	#[d]	#[d]	0.008[b]
4T4-6	-	-	0.002	0.001	0.004	0.007	#[d]	#[d]	0.002[b]
4T4-7	-	-	0.001	0.001	0.004	0.005	#[d]	#[d]	0.002[b]
4T4-8	-	-	0.002	0.001	0.004	0.005	#[d]	#[d]	0.002[b]
4T4-9	-	-	0.002	0.001	0.002	0.003	#[d]	#[d]	0.001[b]
4T4-10	-	-	0.001	0.001	0.002	0.002	#[d]	#[d]	0.001[b]
4T4-11	-	-	0.002	0.002	0.012	0.019	#[d]	#[d]	0.008[b]
4T4-12	-	-	-	0.002	0.010	0.016	#[d]	#[d]	0.006[b]
4T4-13	-	-	-	-	-	-	#[d]	#[d]	0.001[b]
4T4-14	-	-	-	-	-	-	#[d]	#[d]	0.001[b]
4T4-15	-	-	-	-	-	-	#[d]	#[d]	0.003[b]
4T4-16	-	-	-	-	-	-	#[d]	#[d]	0.012[b]
4T4-17	-	-	-	-	-	-	#[d]	#[d]	0.013[b]
4T4-18	-	-	-	-	-	-	#[d]	#[d]	0.009[b]
4T4-19	-	-	-	-	-	-	#[d]	#[d]	0.003[b]
4T4-20	-	-	-	-	-	-	#[d]	#[d]	0.002[b]
4S1-1	-	-	-	-	0.035	0.043	0.052[b]	0.052[b]	0.032[b]
4S2-1	-	-	-	-	0.003	0.002	0.002[d]	0.001[b]	0.001[d]
4S3-1	-	-	-	-	0.036	0.095	0.028[b]	0.030[b]	0.035[b]

a = antennas not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 A current.

\- = measurement point not established.
/ = measurement not taken.
= measurement precluded by antenna operation.

TABLE D-6. 76 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Upland Flora and Soil Microflora Studies
(page 1 of 2)

Site No., Meas. Pt.	1986 NS 4 A	1986 NEW 6 A	1986 SEW 6 A	1986 SEW 10 A, EX	1987 NS 15 A	1987 EW 15 A	1988 NS 75 A	1988 EW 75 A	1989 B 150 A	1990 B 150 A	1991 NS 150 A	1991 B 150 A
4C1-6	<	<	<	*	<	<	<	<	<	<	/	/
4C1-7	<	<	<	*	<	<	<	<	<	<	/	/
4C1-8	<	<	<	*	<	<	<	<	<	<	/	/
4C1-9	<	<	<	*	<	<	<	<	<	<	/	/
4C1-10	<	<	<	*	<	<	<	<	<	<	/	/
4C1-11	<	<	<	*	<	<	<	<	<	<	/	/
4C1-12	<	<	<	*	<	<	<	<	<	<	/	/
4C1-13	<	<	<	*	<	<	<	<	<	<	/	/
4T2-3	<	<	0.004	0.007	0.002	0.014	0.006	0.125	0.142	0.110	0.047	0.122
4T2-4	<	<	0.005	0.008	0.001	0.014	0.017	0.113	0.149	0.122	0.041	0.095
4T2-5	0.018	<	0.092	0.153	0.003	0.23	0.033	2.6	1.31	1.16	0.30	1.08
4T2-6	<	<	0.005	0.008	0.003	0.013	0.014	0.142	0.138	0.148	0.051	0.123
4T2-7	<	<	0.007	0.012	0.001	0.018	0.020	0.165	0.173	0.177	0.044	0.150
4T2-8	<	<	0.004	0.007	0.002	0.012	/	/	0.124	0.112	0.045	0.103
4T2-9	<	<	0.005	0.008	0.002	0.010	0.019	0.137	0.116	0.119	0.031	0.110
4T2-10	<	<	0.004	0.007	0.002	0.011	0.020	0.112	0.113	0.076	0.034	0.112
4T2-11	<	<	0.003	0.005	0.002	0.012	0.010	0.130	0.22	0.180	0.042	0.132
4T2-12	<	<	0.002	0.003	0.002	0.014	/	/	0.095	0.096	0.041	0.086
4T2-13	<	<	0.005	0.008	0.002	0.012	0.010	0.121	0.125	0.130	0.036	0.125
4T2-14	0.030	<	0.155	0.26	0.003	0.186	0.026	2.5	1.66	1.94	0.23	1.68
4T2-15	-	-	-	-	-	-	-	-	2.3	1.67	0.32	0.58
4T2-16	-	-	-	-	-	-	-	-	1.92	1.84	0.46	1.17
4T2-17	-	-	-	-	-	-	-	-	0.69	0.59	0.075	0.27
4T2-18	-	-	-	-	-	-	-	-	0.28	0.21	0.039	0.152
4T2-19	-	-	-	-	-	-	-	-	0.107	0.105	0.029	0.092
4T2-26	-	-	-	-	-	-	-	-	-	0.182	0.059	0.136
4T2-33	-	-	-	-	-	-	-	-	-	0.141	0.042	0.146
4T2-34	-	-	-	-	-	-	-	-	-	0.144	0.041	0.129
4T2-35	-	-	-	-	-	-	-	-	-	0.24	0.101	0.38
4T4-36	-	-	-	-	-	-	-	-	-	4.7	0.94	4.7

TABLE D-6. 76 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Upland Flora and Soil Microflora Studies
(page 2 of 2)

	1986				1987		1988		1989	1990	1991	
Site No., Meas. Pt.	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	NS 150 A	B 150 A
4T4-4	<	<	0.006	0.010	0.002	0.005	0.008	0.028	0.067	0.058	0.015	0.071
4T4-5	0.033	0.008	0.20	0.33	0.019	0.27	0.089	1.31	4.8	3.8	1.37	4.4
4T4-6	0.005	<	0.023	0.038	0.002	0.021	0.011	0.064	0.175	0.117	0.040	0.186
4T4-7	<	<	0.006	0.010	0.002	0.015	0.008	0.090	0.133	0.129	0.026	0.33
4T4-8	<	<	0.008	0.013	0.002	0.016	0.007	0.083	0.145	0.145	0.032	0.130
4T4-9	<	<	0.009	0.015	0.001	0.008	0.009	0.047	0.095	0.072	0.017	0.130
4T4-10	<	<	0.007	0.012	0.001	0.001	0.011	0.057	0.112	0.085	0.026	0.107
4T4-11	<	0.005	0.38	0.63	0.025	0.43	0.20	4.4	5.0	4.6	1.37	4.8
4T4-12	0.055	0.005	0.43	0.72	0.017	0.30	0.150	2.1	4.5	3.8	1.26	4.6
4T4-13	-	-	-	-	-	-	-	-	0.26	0.21	0.042	0.28
4T4-14	-	-	-	-	-	-	-	-	0.88	0.84	0.194	0.[illegible]0
4T4-15	-	-	-	-	-	-	-	-	2.7	2.6	0.51	2.8
4T4-16	-	-	-	-	-	-	-	-	5.9	5.4	1.68	6.7
4T4-17	-	-	-	-	-	-	-	-	4.5	4.3	1.28	5.7
4T4-18	-	-	-	-	-	-	-	-	4.8	3.8	1.24	4.9
4T4-19	-	-	-	-	-	-	-	-	1.16	0.96	0.25	1.15
4T4-20	-	-	-	-	-	-	-	-	0.32	0.183	0.067	0.47
4S1-1	-	-	-	-	<	<	<	<	<	<	<	<
4S2-1	-	-	-	-	<	<	<	<	<	<	<	<
4S3-1	-	-	-	-	<	<	<	<	<	<	<	<

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.
A = amperes.

\- = measurement point not established.
/ = measurement not taken.
< = measurement est. <0.001 V/m based on earth E-field.
* = data cannot be extrapolated.

TABLE D-7. 76 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Studies
(page 1 of 2)

Site No., Meas. Pt.	1986 NS 4 A	1986 NEW 6 A	1986 SEW 6 A	1986 SEW 10 A, EX	1987 NS 15 A	1987 EW 15 A	1988 NS 75 A	1988 EW 75 A	1989 B 150 A	1990 B 150 A	1991 NS 150 A	1991 B 150 A
4C1-6	<0.001	<0.001	<0.001	*	0.002	0.002	0.007	0.005	0.030	0.028	/	0.026
4C1-7	<0.001	<0.001	<0.001	*	0.005	0.006	0.024	0.023	0.091	0.085	/	0.079
4C1-8	<0.001	<0.001	<0.001	*	0.004	0.004	0.017	0.016	0.076	0.067	/	0.069
4C1-9	<0.001	<0.001	<0.001	*	0.002	0.002	0.007	0.006	0.030	0.022	/	0.028
4C1-10	<0.001	<0.001	<0.001	*	0.005	0.004	0.026	0.023	0.087	0.079	/	0.089
4C1-11	<0.001	<0.001	<0.001	*	0.006	0.005	0.028	0.028	0.113	0.103	/	0.101
4C1-12	<0.001	<0.001	<0.001	*	0.004	0.003	0.016	0.016	0.068	0.072	/	0.053
4C1-13	<0.001	<0.001	<0.001	*	0.002	0.002	0.012	0.011	0.051	0.044	/	0.037
4T2-3	1.31	0.22	6.3	10.5	1.36	15.2	7.7	76	131	140	22	126
4T2-4	1.05	0.22	5.0	8.3	1.70	10.7	6.2	68	135	129	44	134
4T2-5	1.18	0.24	5.3	8.8	1.46	12.7	8.2	62	86	105	41	123
4T2-6	1.11	0.27	4.4	7.3	2.2	12.4	10.4	56	105	101	39	114
4T2-7	1.13	0.23	5.3	8.8	1.31	9.7	8.8	71	90	89	28	94
4T2-8	1.32	0.25	5.7	9.5	1.81	15.8	/	/	141	135	40	139
4T2-9	1.17	0.21	5.1	8.5	1.46	13.7	7.1	63	119	125	40	121
4T2-10	0.97	0.22	4.1	6.8	1.84	10.5	8.1	50	96	91	35	98
4T2-11	1.14	0.21	5.0	8.3	2.2	10.7	9.6	122	182	170	38	155
4T2-12	1.06	0.21	4.3	7.2	1.93	13.5	/	/	99	114	45	119
4T2-13	1.12	0.64	5.4	9.0	1.74	14.9	8.2	71	138	144	36	142
4T2-14	1.07	0.175	5.1	8.5	1.66	14.3	6.6	56	124	121	42	138
4T2-15	-	-	-	-	-	-	-	-	73	82	32	82
4T2-16	-	-	-	-	-	-	-	-	88	86	33	92
4T2-17	-	-	-	-	-	-	-	-	104	105	29	107
4T2-18	-	-	-	-	-	-	-	-	95	99	29	124
4T2-19	-	-	-	-	-	-	-	-	107	107	31	103
4T2-26	-	-	-	-	-	-	-	-	-	210	57	189
4T2-33	-	-	-	-	-	-	-	-	-	113	41	130
4T2-34	-	-	-	-	-	-	-	-	-	152	36	127
4T2-35	-	-	-	-	-	-	-	-	-	136	45	137
4T2-36	-	-	-	-	-	-	-	-	-	155	44	133

TABLE D-7. 76 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Studies
(page 2 of 2)

Site No., Meas. Pt.	1986				1987		1988		1989	1990	1991	
	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	NS 150 A	B 150 A
4T4-4	0.33	0.181	1.46	2.4	1.63	3.7	7.2	16.5	42	31	10.2	25
4T4-5	13.8	2.0	81.	135.	14.0	194.	68	910	2100	1670	510	1790
4T4-6	1.22	0.22	6.2	10.3	2.2	12.9	10.3	62	140	117	29	141
4T4-7	0.94	0.175	5.5	9.2	2.0	14.1	9.1	62	119	135	30	101
4T4-8	0.91	0.188	5.3	8.8	1.36	10.7	6.8	65	106	113	31	111
4T4-9	0.29	0.130	1.32	2.2	1.08	3.0	7.5	18.1	47	42	4.5	18
4T4-10	0.29	0.169	1.63	2.7	1.35	3.9	5.1	16.0	39	43	8.1	30
4T4-11	0.59	1.82	89.	148.	10.7	178.	50	850	1870	1890	630	2200
4T4-12	21.	2.2	118.	197.	13.8	260.	40	760	1950	1600	380	1380
4T4-13	-	-	-	-	-	-	-	-	64	56	15.2	59
4T4-14	-	-	-	-	-	-	-	-	220	200	59	320
4T4-15	-	-	-	-	-	-	-	-	760	760	220	820
4T4-16	-	-	-	-	-	-	-	-	3000	3800	690	3300
4T4-17	-	-	-	-	-	-	-	-	130	30	/	/
4T4-18	-	-	-	-	-	-	-	-	3200	3600	1000	4100
4T4-19	-	-	-	-	-	-	-	-	750	880	196	880
4T4-20	-	-	-	-	-	-	-	-	200	163	49	200
4S1-1	-	-	-	-	<0.001	<0.001	<0.001	<0.001	/	/	/	/
4S2-1	-	-	-	-	0.005	0.005	0.026	0.026	0.126	0.103	/	0.097
4S3-1	-	-	-	-	<0.001	<0.001	<0.001	<0.001	/	/	/	/

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.
A = amperes.

- = measurement point not established.
/ = measurement not taken.
* = data cannot be extrapolated.

TABLE D-8. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Upland Flora and Soil Microflora Studies
(page 1 of 2)

Site No., Meas. Pt.	1986				1987		1988		1989	1990	1991	
	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	NS 150 A	B 150 A
4C1-6	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.001	0.001	0.003	0.003	/	0.003
4C1-7	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.001	<0.001	0.002	0.002	/	0.002
4C1-8	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.001	<0.001	0.002	0.002	/	0.002
4C1-9	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.001	0.001	0.003	0.003	/	0.003
4C1-10	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.001	<0.001	0.002	0.002	/	0.002
4C1-11	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.001	<0.001	0.002	0.002	/	0.002
4C1-12	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.001	<0.001	0.002	0.002	/	0.002
4C1-13	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.001	0.001	0.003	0.003	/	0.003
4T2-3	0.047	0.001	0.22	0.37	0.008	0.55	0.040	2.8	5.7	5.9	1.69	5.5
4T2-4	0.049	0.001	0.24	0.40	0.008	0.57	0.041	2.9	5.8	5.9	1.74	5.7
4T2-5	0.197	<0.001	1.00	1.67	0.011	2.4	0.061	12.4	24	27	6.9	23
4T2-6	0.058	0.001	0.44	0.73	0.006	1.16	0.020	5.0	10.3	11	3.0	10.3
4T2-7	0.046	0.001	0.22	0.37	0.006	0.59	0.024	2.6	5.4	5.8	1.63	5.4
4T2-8	0.045	0.001	0.22	0.37	0.006	0.59	/	/	5.6	5.8	1.67	5.3
4T2-9	0.029	0.001	0.138	0.23	0.007	0.38	0.027	1.72	3.4	3.6	0.96	3.3
4T2-10	0.033	0.001	0.149	0.25	0.006	0.39	0.027	1.78	3.5	3.7	1.14	3.4
4T2-11	0.043	0.001	0.21	0.35	0.006	0.56	0.025	2.6	5.0	5.3	1.54	4.9
4T2-12	0.047	0.001	0.23	0.38	0.006	0.61	/	/	5.6	5.9	1.71	5.7
4T2-13	0.086	<0.001	0.43	0.72	0.005	1.14	0.020	5.1	10.1	10.8	3.1	10.4
4T2-14	0.21	<0.001	1.03	1.72	0.012	2.5	0.061	11.9	25	28	7.7	26
4T2-15	-	-	-	-	-	-	-	-	33	36	9.6	32
4T2-16	-	-	-	-	-	-	-	-	28	29	7.8	26
4T2-17	-	-	-	-	-	-	-	-	13.6	13.9	3.9	13.0
4T2-18	-	-	-	-	-	-	-	-	8.6	8.6	2.4	7.7
4T2-19	-	-	-	-	-	-	-	-	5.9	6.0	1.73	5.7
4T2-26	-	-	-	-	-	-	-	-	-	10.5	2.8	9.7
4T2-33	-	-	-	-	-	-	-	-	-	4.2	1.21	3.8
4T2-34	-	-	-	-	-	-	-	-	-	7.4	2.1	7.0
4T2-35	-	-	-	-	-	-	-	-	-	21	5.9	20
4T2-36	-	-	-	-	-	-	-	-	-	36	10.0	33

TABLE D-8. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Upland Flora and Soil Microflora Studies
(page 2 of 2)

Site No., Meas. Pt.	1986 NS 4 A	1986 NEW 6 A	1986 SEW 6 A	1986 SEW 10 A, EX	1987 NS 15 A	1987 EW 15 A	1988 NS 75 A	1988 EW 75 A	1989 B 150 A	1990 B 150 A	1991 NS 150 A	1991 B 150 A
4T4-4	0.019	<0.001	0.096	0.160	0.005	0.24	0.027	1.15	2.5	2.3	0.63	2.3
4T4-5	0.114	0.001	0.57	0.95	0.008	1.40	0.033	6.9	13.9	13.3	4.2	13.7
4T4-6	0.045	0.001	0.22	0.37	0.008	0.53	0.034	2.7	5.3	5.1	1.60	5.3
4T4-7	0.038	0.001	0.186	0.31	0.008	0.45	0.033	2.3	4.4	4.1	1.30	4.4
4T4-8	0.035	0.001	0.179	0.30	0.007	0.43	0.033	2.1	4.2	4.1	1.25	4.2
4T4-9	0.025	0.21	0.118	0.197	0.005	0.29	0.027	1.41	2.8	2.7	0.79	2.8
4T4-10	0.022	<0.001	0.116	0.193	0.005	0.27	0.027	1.33	2.7	2.6	0.75	2.8
4T4-11	0.161	0.001	0.80	1.33	0.011	1.89	0.042	8.9	18.7	19.1	5.9	18.3
4T4-12	0.115	0.001	0.58	0.97	0.010	1.37	0.041	7.1	14.5	13.4	4.4	14.0
4T4-13	-	-	-	-	-	-	-	-	2.7	3.8	1.12	4.0
4T4-14	-	-	-	-	-	-	-	-	7.0	7.0	2.0	7.4
4T4-15	-	-	-	-	-	-	-	-	11.9	12.0	3.4	11.5
4T4-16	-	-	-	-	-	-	-	-	18	14.6	5.2	14.7
4T4-17	-	-	-	-	-	-	-	-	14.3	13.6	4.3	13.8
4T4-18	-	-	-	-	-	-	-	-	16.8	15.7	5.0	15.8
4T4-19	-	-	-	-	-	-	-	-	9.8	9.1	2.8	9.7
4T4-20	-	-	-	-	-	-	-	-	5.9	5.4	1.76	5.9
4S1-1	-	-	-	-	<0.001	<0.001	<0.001	<0.001	/	/	/	/
4S2-1	-	-	-	-	<0.001	<0.001	0.001	<0.001	0.002	0.001	/	0.002
4S3-1	-	-	-	-	<0.001	<0.001	<0.001	<0.001	/	/	/	/

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.
A = amperes.

\- = measurement point not established.
/ = measurement not taken.
* = data cannot be extrapolated.

TABLE D-9. 1990 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Antenna Site Fixed Test Points

Test Point	Measurement Date												Summary Statistics		
	6/28	7/10	7/24	8/07	8/21	9/04	9/18	10/02	10/22	11/07	12/05	12/21	Mean	SD	Coeff. of Variab.
4T2-3	140	135	139	145	142	141	139	141	143	147	153	157	144	6.0	0.042
4T2-4	129	128	124	125	126	127	126	126	126	125	120	121	125	2.5	0.020
4T2-5	105	99	97	94	102	99	104	105	111	108	110	106	103	5.0	0.049
4T2-6	101	100	96	97	100	94	96	97	106	104	104	105	100	3.9	0.039
4T2-7	89	86	84	82	80	84	81	85	87	87	88	83	85	2.7	0.032
4T2-8	135	130	142	143	132	138	133	137	141	143	141	145	138	4.7	0.034
4T2-9	125	122	119	116	120	118	117	119	122	122	136	141	123	7.4	0.060
4T2-10	91	87	88	88	87	89	88	92	97	95	96	98	91	4.0	0.043
4T2-11	170	168	160	158	168	165	168	168	177	171	123	125	160	16.8	0.105
4T2-12	114	144	113	114	110	110	106	108	114	116	154	163	122	18.8	0.154
4T2-13	144	142	144	145	144	146	146	143	147	146	156	160	147	5.2	0.035
4T2-14	121	115	117	113	118	117	122	124	127	126	122	125	121	4.3	0.036
4T2-16	91	88	85	81	90	91	90	96	97	99	94	95	91	5.0	0.054
4T2-19	107	106	106	103	106	105	106	106	107	107	105	106	106	1.10	0.010
4T2-20	107	107	102	108	107	105	106	107	111	110	114	121	109	4.7	0.043
4T2-21	143	139	122	132	139	142	139	140	149	144	141	144	140	6.6	0.047
4T2-22	98	92	91	85	93	86	89	93	90	89	85	85	90	3.9	0.043
4T2-23	114	108	109	107	112	109	115	115	126	122	113	115	114	5.4	0.047
4T2-24	120	121	114	112	117	117	120	123	127	126	128	123	121	4.8	0.040
4T2-25	115		117	121	116	114	115	114	118	120	129	129	119	5.2	0.044
4T2-26	210	200	200	210	210	199	198	197	210	220	230	220	210	9.4	0.045
4T2-27	118	112	124	130	119	116	115	116	129	133	124	131	122	6.9	0.056
4T2-28	151	151	153	157	152	153	152	153	149	151	152	149	152	2.0	0.013
4T2-29	55	55	61	63	53	53	54	53	53	59	53	54	56	3.4	0.060
4T2-30	106	105	113	122	110	107	112	113	115	124	120	122	114	6.3	0.055
4T2-31	94	96	98	99	99	100	101	100	102	102	103	104	100	2.8	0.028
4T2-32	75	73	73	72	74	74	75	74	75	73	72	75	74	1.10	0.015

TABLE D-10. 1991 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Antenna Site Fixed Test Points

Test Point	Measurement Date																	Summary Statistics*		
						NS Antenna Only														
	1/4	1/18	2/19	3/18	4/25	5/29	6/21	7/8	7/25	8/16	8/28	9/9	9/30	10/11	10/23	11/8	12/6	Mean	SD	Coeff. of Variab.
4T2-3	147	144	146	153	152	48	49	49	153	159	160	150	150	148	149	149	140	150	5.1	0.034
4T2-4	112	117	112	128	131	44	44	43	135	136	138	139	136	130	135	124	129	129	8.9	0.069
4T2-5	108	111	132	130	111	35	34	35	118	112	108	118	120	120	119	122	122	118	7.1	0.061
4T2-6	112	119	113	112	109	38	37	40	109	121	120	112	113	116	114	114	116	114	3.6	0.031
4T2-7	95	101	102	97	97	27	26	26	83	84	84	87	90	89	91	90	93	92	5.9	0.065
4T2-8	149	150	150	146	147	43	42					137	134	139	140	144	153	145	5.9	0.041
4T2-9	137	134	141	138	128	37	38						165	164	156		140	145	12.7	0.088
4T2-10	100	99	98	101	100	35	35	35	96	102	103	95	103	103	105	103	102	101	2.8	0.028
4T2-11	139	131	136	128	167	50	41	55	173	144	106	167	166	165	162	172	119	148	21	0.143
4T2-12	161	162	165	151	132	39	45	39	124	131	132	129	120	123	124	136	160	139	16.1	0.115
4T2-13	180	169	167	149	139	41	43	41	150	149	146	148	147	149	150	149	149	153	10.6	0.070
4T2-14	113	121	119	126	131	39	39	39	128	128	133	127	133	130	135	123	128	127	5.8	0.046
4T2-15										58	60	65	66	64	65	63	59	63	2.9	0.046
4T2-16	81	85	87	100	101	33	34					108	118	114	120		100	101	13.1	0.129
4T2-17										99	92	111	109	111	111	111	100	106	7.0	0.066
4T2-18										118	116	112	108	110	110	110	103	111	4.3	0.039
4T2-19	98	103	99	106	104	33	33					107	116	101	108	124	103	106	7.3	0.069
4T2-20	129	122	123	121	117	39	39	38	116	113	114	112	112	114	114	113	106	116	5.6	0.048
4T2-21	141	128	135	140	145	57	52	54	144	135	82	140	131	130	127	132	120	131	15.1	0.116
4T2-22	86	89	94	91	109	43	40	43	98	86	86	99	104	94	97	88	94	94	6.7	0.072
4T2-23	106	107	108	120	117	40	35	39	116	116	114	129	129	127	129	123	107	118	8.4	0.071
4T2-24	121	130	132	133	133	37	36	36	122	115	120	124	124	125	126	118	124	125	5.4	0.043
4T2-25	138	135	132	125	107	28	15	4.5	88	69	76	57	61	65	63	124	103	96	30	0.31
4T2-26	250	240	230	220	230	67	62			200	192	220	210	210	210	240	240	220	15.8	0.071
4T2-27	149	146	146	134	138	37	30	37	129	135	131	122	126	132	130	155	130	136	9.2	0.068
4T2-28	178	168	164	154	153	52	55	54	162	167	155	156	153	157	153	153	150	159	7.6	0.048
4T2-29	70	70	78	73	72	15	14	15	64	66	66	54	54	58	56	64	58	65	7.3	0.114
4T2-30	130	129	131	124	128	40	38	40	116	125	67	107	114	121	120	132	120	119	16.0	0.134
4T2-31	103	104	105	104	98	37	39	38	106	97	91	108	108	107	109	103	100	103	4.9	0.047
4T2-32	58	63	61	77	80	28	28	28	76	74	74	82	79	77	80	76	84	74	7.7	0.104
4T2-33										114	138	116	116	114	117	126	122	120	7.7	0.064
4T2-34										97	100	118	110	111	112	114	119	110	7.4	0.067
4T2-35											162	155	155	161	158	179	163	162	7.6	0.047
4T2-36											128	142	140	136	135	136	142	137	4.6	0.033

*Summary statistics do not include data measured during operation of the NS antenna only.

TABLE D-11. 1990 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Ground Site Fixed Test Points

Test Point	Measurement Date												Summary Statistics		
	6/28	7/10	7/24	8/07	8/21	9/04	9/18	10/2	10/22	11/7	12/5	12/21	Mean	S.D.	Coeff.of Variab.
4T4-4	31	29	27	28	31	31	32	32	12	9	8.7	8.3	23	9.9	0.42
4T4-5	1670	1800	1830	1950	2100	2000	2000	1980	1720	1740	1980	1910	1900	134	0.071
4T4-6	117	115	115	125	136	138	141	143	148	140	142	140	133	11.4	0.086
4T4-7	135	132	130	132	137	135	137	139	144	146	145	149	138	6.0	0.043
4T4-8	113	108	105	106	109	105	108	109	112	113	109	111	109	2.7	0.025
4T4-9	42	42	42	43	42	43	43	44	18	20	20	22	35	10.7	0.31
4T4-10	32	30	30	30	30	29	32	33	35	37	37	37	33	3.0	0.090
4T4-11	1890	1940	2200	2300	2000	2100	2000	2000	2200	2200	2400	2500	2200	185	0.086
4T4-12	1600	1610	1700	1820	1850	1820	1900	1960	1820	1770	1820	1860	1790	104	0.058
4T4-21	109	107	91	97	122	127	131	134	146	135	132	136	122	16.5	0.135
4T4-22	148	137	139	148	153	154	159	169	177	174	170	165	158	12.8	0.081
4T4-23	330	340	330	350	380	370	390	400	410	380	370	390	370	25	0.069
4T4-24	360	360	340	340	390	380	410	430	430	420	420	420	390	32	0.081

TABLE D-12. 1991 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Ground Site Fixed Test Points

Test Point	Measurement Date																	Summary Statistics*		
						NS Antenna Only														
	1/4	1/18	2/19	3/18	4/25	5/29	6/21	7/8	7/25	8/16	8/28	9/13	9/30	10/10	10/23	11/6	12/6	Mean	SD	Coeff. of Variab.
4T4-4	6.8	7.1	8.3	10.3	9.2	10.6	9.9	10.4	11.1	11.3	11.5	12.8	12.6	12	13	12	11	10.6	2.0	0.185
4T4-5	2100	2100	2200	2200	1850	480	480	410	1780	1780	1850	1910	1900	1900	1850	1460	1580	1890	210	0.109
4T4-6	131	131	135	135	100	32	29	30	123	125	133	140	141	143	141	132	110	130	11.8	0.091
4T4-7	136	147	135	155	134	37	36										145	142	7.7	0.054
4T4-8	108	112	109	115	108	30	29	29	110	102	102	105	105	108	108	112	110	108	3.6	0.033
4T4-9	25	25	27	26	22	8.0	7.1	7.8	18.2	17.9	18.5	17.9	18.6	19	19	16	19	21	3.5	0.168
4T4-10	37	36	33	27	30	9.4	8.6	9.0	32	31	24	32	33	34	34	36	30	32	3.5	0.109
4T4-11	2600	2800	3200	2900	2400	550	550	480	2000	2200	2400	2100	2100	2100	2200	1790	2000	2300	390	0.167
4T4-12	2500	2300	2600	2700	1890	470	450	380	1550	1520	1580	1700	1800	1900	1830	1400	1520	1910	420	0.22
4T4-13													76	79				78	1.5	0.019
4T4-14												260	220	230	230	200	270	310	128	0.42
4T4-15										640	850	790	790	790	800	710	750	760	60	0.079
4T4-16										3500	3600	3100	3100	3200	3300	3400	3600	3300	194	0.058
4T4-18										4100	4400	4100	4200	4400	4400	4500	5000	4400	270	0.062
4T4-19												750	780	820	840	710	700	770	55	0.072
4T4-20																	220	220	0.0	0.0
4T4-21	128	123	120	149	92	39	34	33	113	89	100	124	130	128	130	111	98	117	16.5	0.141
4T4-22	154	148	143	161	123	52	44	46	133	149	152	156	152	157	160	151	129	148	11.2	0.076
4T4-23	390	380	400	390	310	91	88	83	340	370	390	400	390	400	400	340	320	370	30	0.081
4T4-24	450	440	450	470	350	115	104	100	370	350	360	410	430	430	430	310	370	400	49	0.121

*Summary statistics exclude data measured during operation of the NS antenna only.

APPENDIX E

AQUATIC ECOSYSTEMS STUDIES

AQUATIC ECOSYSTEMS STUDIES

The approach of the aquatic ecosystems studies is to integrate the major interrelated and interactive components of aquatic ecosystems (periphytic algae, aquatic insects, and fish) and to monitor events and processes critical to stream ecosystems. The earth electric field and the magnetic field are considered the most important factors influencing the aquatic ecosystems studies. The electric field in the air is not expected to have any impact on the components of these studies.

IITRI field crews made ELF electromagnetic (EM) field measurements at 16 measurement points within four treatment and five control sites for the aquatic ecosystems studies in 1991. The measurement points differed from those used in 1990 in that four measurement points were dropped (5C1-7, 5T2-5, 5T2-6, and 5T4-2) and one measurement point was added (5T4-3). Measurement point 5T4-3 is a new fyke location for the fish movement study and replaces 5T4-2, which was re-established in 1990 in approximation of the net location. Measurement points 5C1-7, 5T2-5, and 5T2-6 were established in 1990 for the purpose of fine tuning study locations to improve treatment/control exposure ratios. These locations were never used for any study activities and the measurement points were therefore dropped in 1991. Measurement dates for 1991 and previous years appear in Table E-1.

TABLE E-1. EM FIELD MEASUREMENT DATES
Aquatic Ecosystems Studies

Year	Measurement Dates	
1983	Jun 13, 15, 16	
1984	May 16, 17	Aug 21, 22
1985	Jul 22, 23	
1986	Oct 8-10	
1987	Sep 28, 29	
1988	Sep 26, 28-30	
1989	Sep 11-13	
1990	May 8, 9, 11	
1991	May 29, 30	

The positions of the study sites relative to the NRTF-Republic are shown on the composite map in Figure E-1. The site numbers listed on the map are those used by IITRI. Table E-2 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites. Details of measurement locations within sites are given in Figures E-2 through E-8.

TABLE E-2. SITE NUMBER CROSS-REFERENCE
Aquatic Ecosystems Studies

IITRI Site No.	Investigator's Site Name		Location		
			Township	Range	Section(s)
	Ambient Monitoring				
5T2-1	FEX 2		T43N	R29W	14
5C1-1	FCD		T43N	R28W	21
	Insect Substrates and Leaf Packs				
5T1-2	FEX 1		T43N	R29W	14
5T2-7	FEX 2		T43N	R29W	14
5C1-5	FCD		T43N	R28W	21
	Periphyton and PR				
5T2-2	FEX 2		T43N	R29W	14
5T2-7	FEX N		T43N	R29W	14
5C1-3	FCD N		T43N	R28W	21
5C1-5	FCD		T43N	R28W	21
	Periphyton Grazing				
5T2-8	FEX 2		T43N	R29W	14
5C1-3	FCD N		T43N	R28W	21
5C1-5	FCD		T43N	R28W	21
	Fish Movement				
5T2-4	FEX 2		T43N	R29W	14
5T3-1	FEX 3		T43N	R29W	14
5T4-3	FEX 4		T43N	R29W	11, 14
5C1-4	FCD		T43N	R28W	21
5C3-2	FCU		T43N	R29W	18
5C5-1	FS1 (inactive)		T43N	R29W	16
5C14-1	TM		T43N	R29W	8
5C15-1	T-Line		T43N	R29W	17
	Fish Population				
5T3-1	FEX 3		T43N	R29W	14
5C1-4	FCD		T43N	R28W	21
	Inactive Locations				
5T2-5	Unused		T43N	R29W	14
5T2-6	Unused		T43N	R29W	14
5T7-1	Unused		T43N	R29W	11
5C1-7	Unused		T43N	R28W	21
5T2-3	FEX 2; Insect Movement	(abandoned)	T43N	R29W	14
5C1-3	FCU; Insect Movement	(abandoned)	T43N	R28W	21
5C1-6	FCU; Insect Movement	(abandoned)	T43N	R28W	21
5T1-1	FEX 1; Fish Parasites	(abandoned)	T43N	R29W	11
5T4-1	FEX 4; Fish Parasites	(abandoned)	T43N	R29W	14
5T6-1	FEX 6; Fish Parasites	(abandoned)	T43N	R29W	12, 13
5C1-2	FCU; Fish Parasites	(abandoned)	T43N	R28W	21
5T4-2	FEX 4; Fish Feeding	(abandoned)	T43N	R29W	11, 14

EM field measurements for 1991 and previous years are found in Tables E-3 through E-8. Tables E-3, E-4, and E-5 present 60 Hz data for the air electric field, earth electric field, and magnetic flux density, respectively. Tables E-6, E-7, and E-8 present 76 Hz data for these fields as well as the corresponding operating currents of the NRTF-Republic for each year.

Considerable year-to-year variability in the 60 Hz EM fields is evident. The primary factors in this variability are changes in power line loading conditions (which are unknown) and differences in the configuration of the antennas at the time of measurement. Notes on the antenna configurations are included in the tables primarily for engineering use. The 60 Hz measurements in 1986-1991 (excluding 1989) were taken while the antennas were off, and are representative of 60 Hz levels present during maintenance periods. In 1989, measurements were taken at some treatment sites during full-power operation of the antennas with an unmodulated signal. These values indicate that 60 Hz EM fields present during operation of the antennas are comparable to those present when the antennas are off.

Annual variations in the 60 Hz fields measured at the control study sites are also caused by differences in power line loading, but are not dependent on the antennas or their configuration because of the distance of these sites from the antennas. The 60 Hz field values at the control site, nonetheless, are about as variable as those at the treatment site.

Overall, the 60 Hz EM fields measured at both treatment and control study sites in 1991 are consistent with previous field values and with the expected differences in power line loads and the antenna configuration. Regardless of the field variability associated with the measurement condition, 76 Hz EM fields at the treatment site consistently dominate the 60 Hz EM fields at both the treatment and control sites, and the ratios of 60 Hz EM fields between the treatment and control sites continue to meet exposure criteria guidelines established at the beginning of the study. One exception to this is the T-line crossing for the fish movement study, where the 60 Hz EM fields dominate the 76 Hz EM fields. Study protocol modifications to account for this inevitable EM field disparity were implemented in 1990 and are described in a previous report.[11]

The 76 Hz EM field measurements in 1991 were made during operation of the NS antenna only with 150-ampere antenna currents, the predominant operating current of the NRTF-Republic since 4 May 1989. The antenna currents at which measurements were made in each year are given in the column headings of Tables E-6 through E-8. The annual increases in field magnitudes reflect the level of antenna current at the time of measurement: 4 or 6 amperes in 1986, 15 amperes in 1987, 75 amperes in 1988, and 150 amperes in 1989, and 1991. Shutdown of the EW antenna does not appear to have had a significant effect on the 76 Hz EM exposure levels at these study sites. EM field measurements, which were made at these study sites in 1991 while the EW antenna was shutdown, are comparable to those conducted in previous years during operation of both antennas. This period of single antenna operation can therefore be treated as a full exposure operation period.

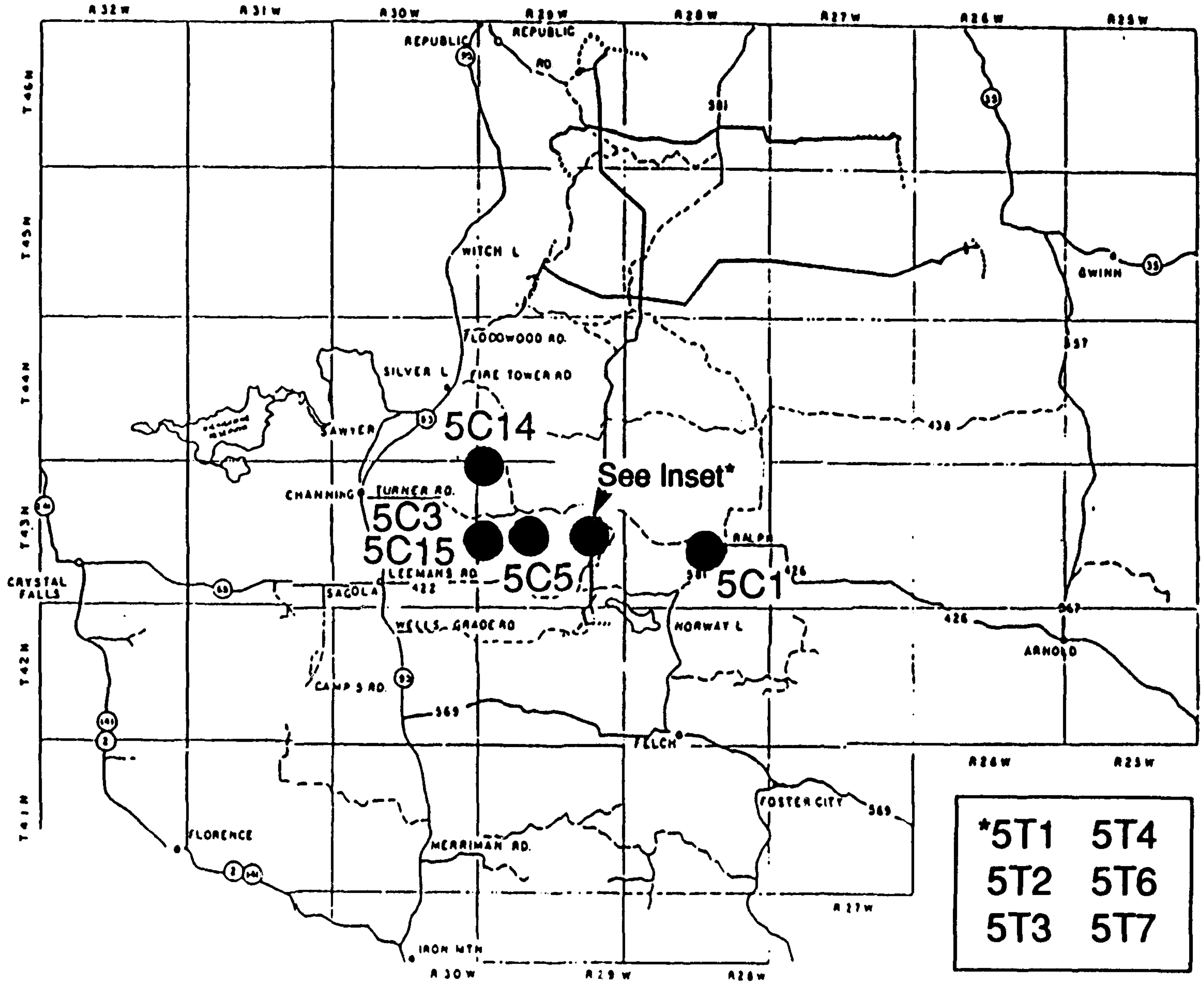


FIGURE E-1. POSITIONS OF AQUATIC ECOSYSTEMS RELATIVE TO NRTF-REPUBLIC ANTENNA ELEMENTS.

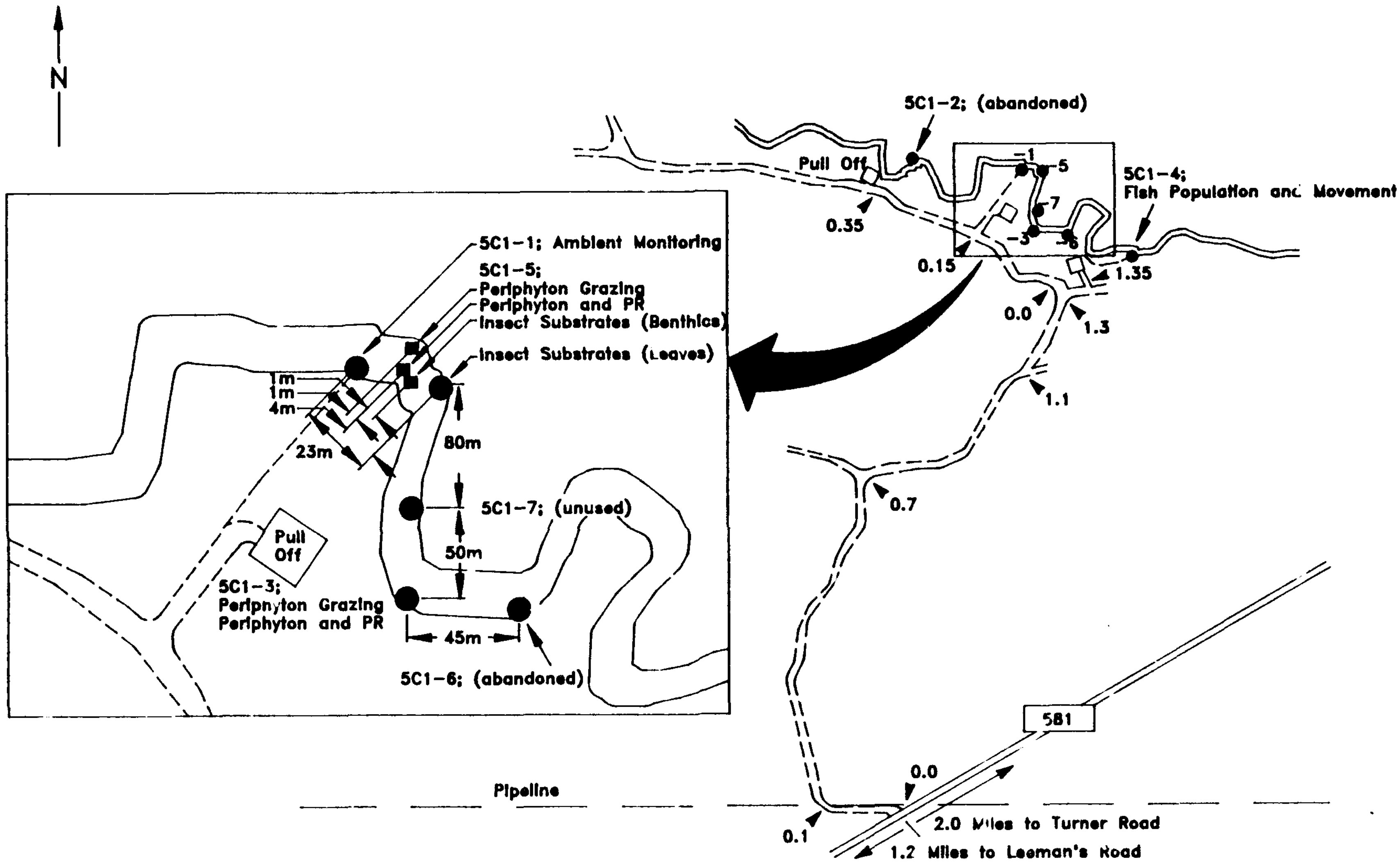


FIGURE E-2. MEASUREMENT POINTS AT FCD; 5C1-1 THROUGH 7.

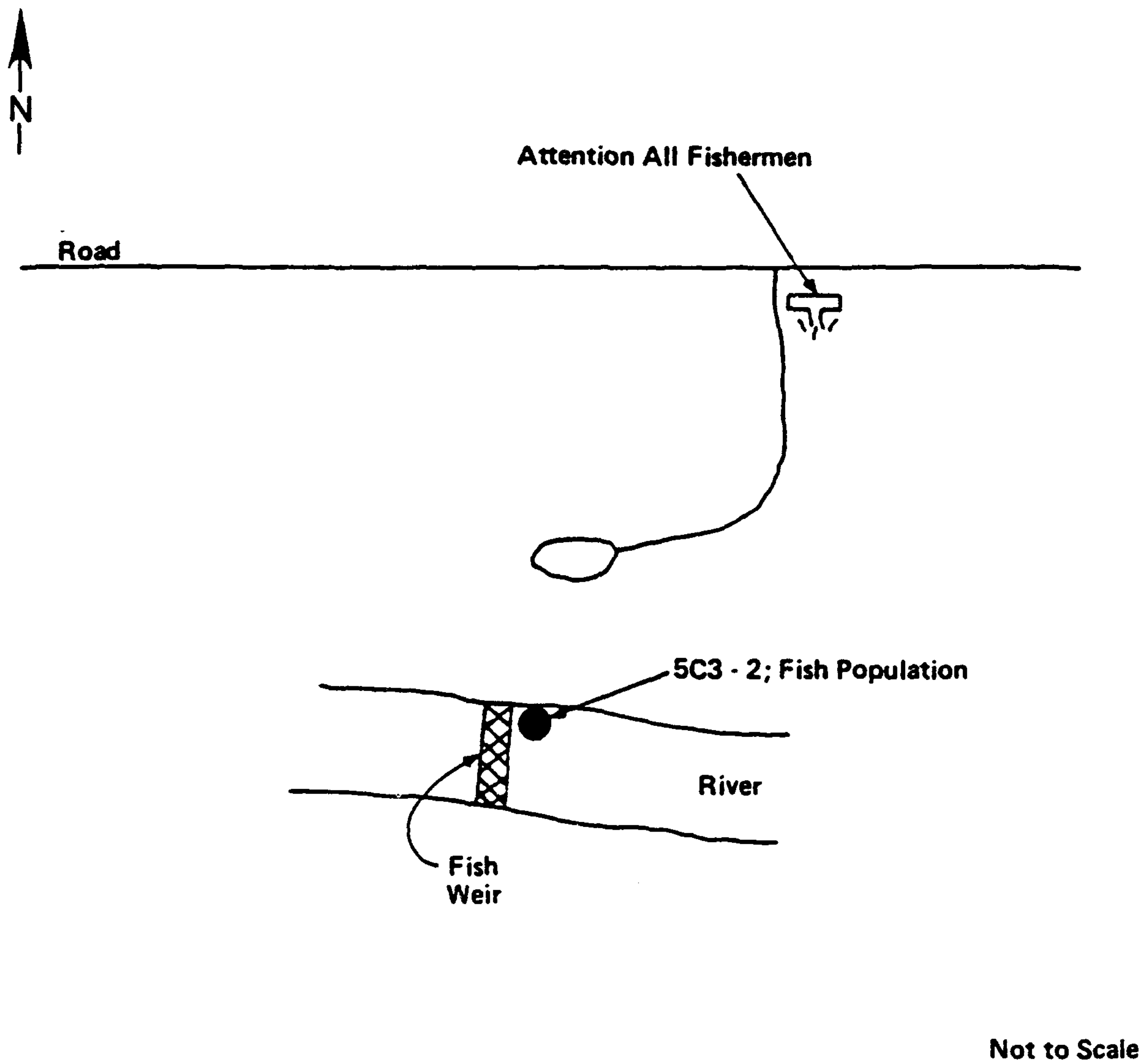


FIGURE E-3. MEASUREMENT POINT AT FCU; 5C3-2.

60297/190

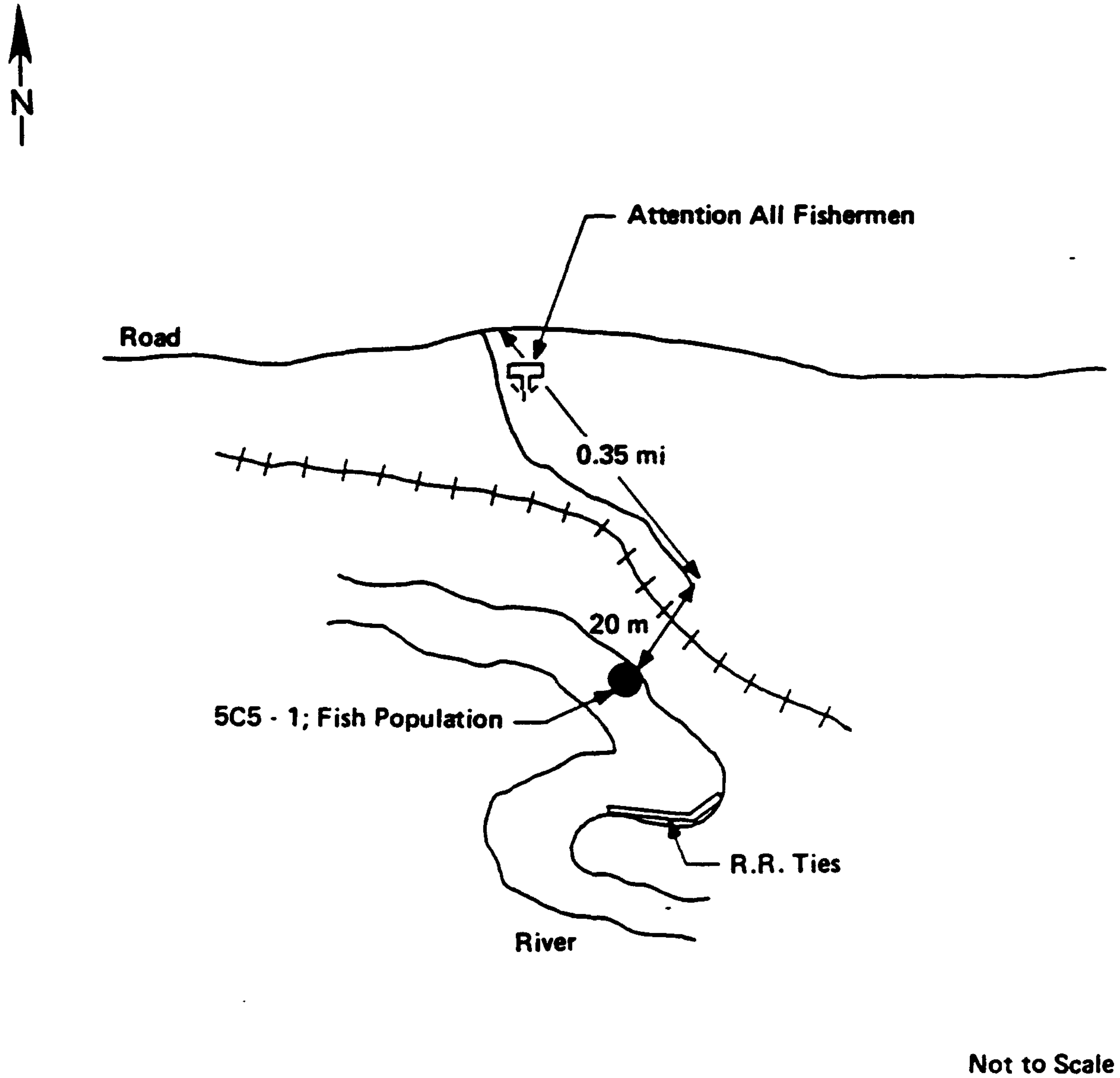
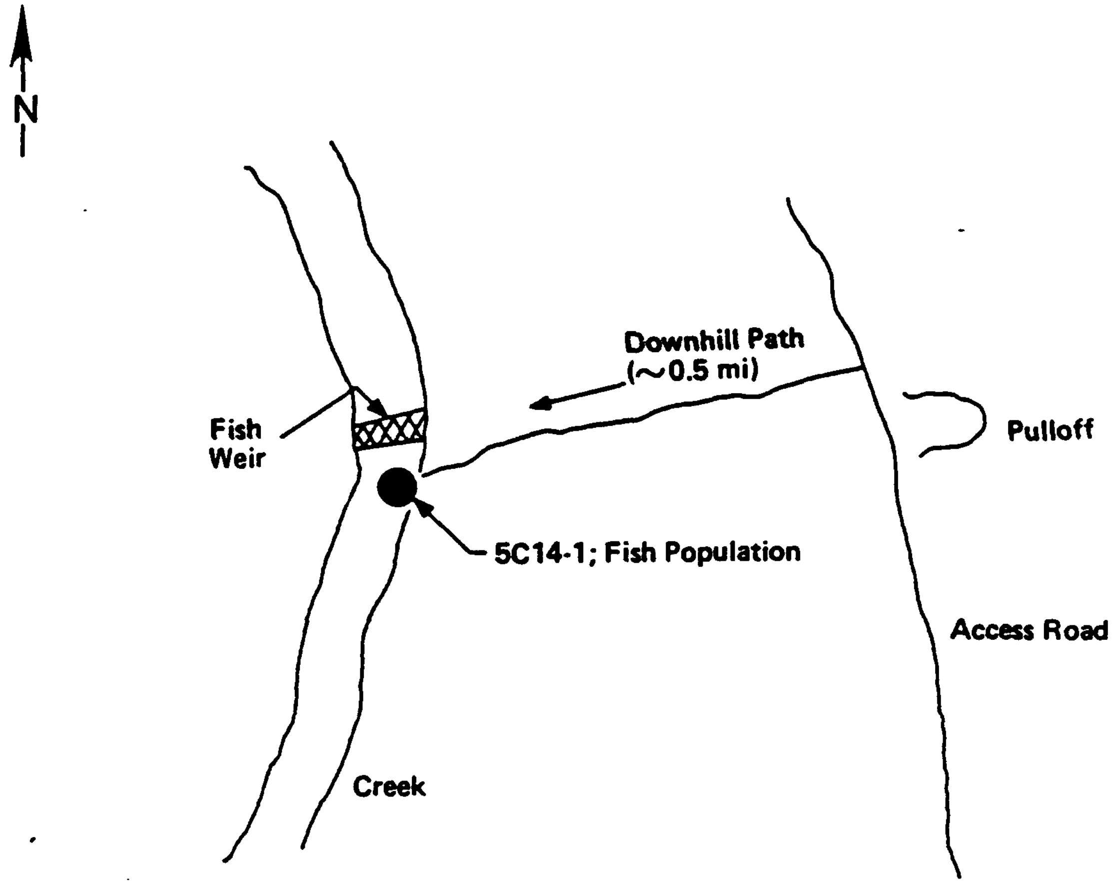


FIGURE E-4. MEASUREMENT POINT AT FS1; 5C5-1.

60297/790



Not to Scale

FIGURE E-5. MEASUREMENT POINT AT TM; 5C14-1.

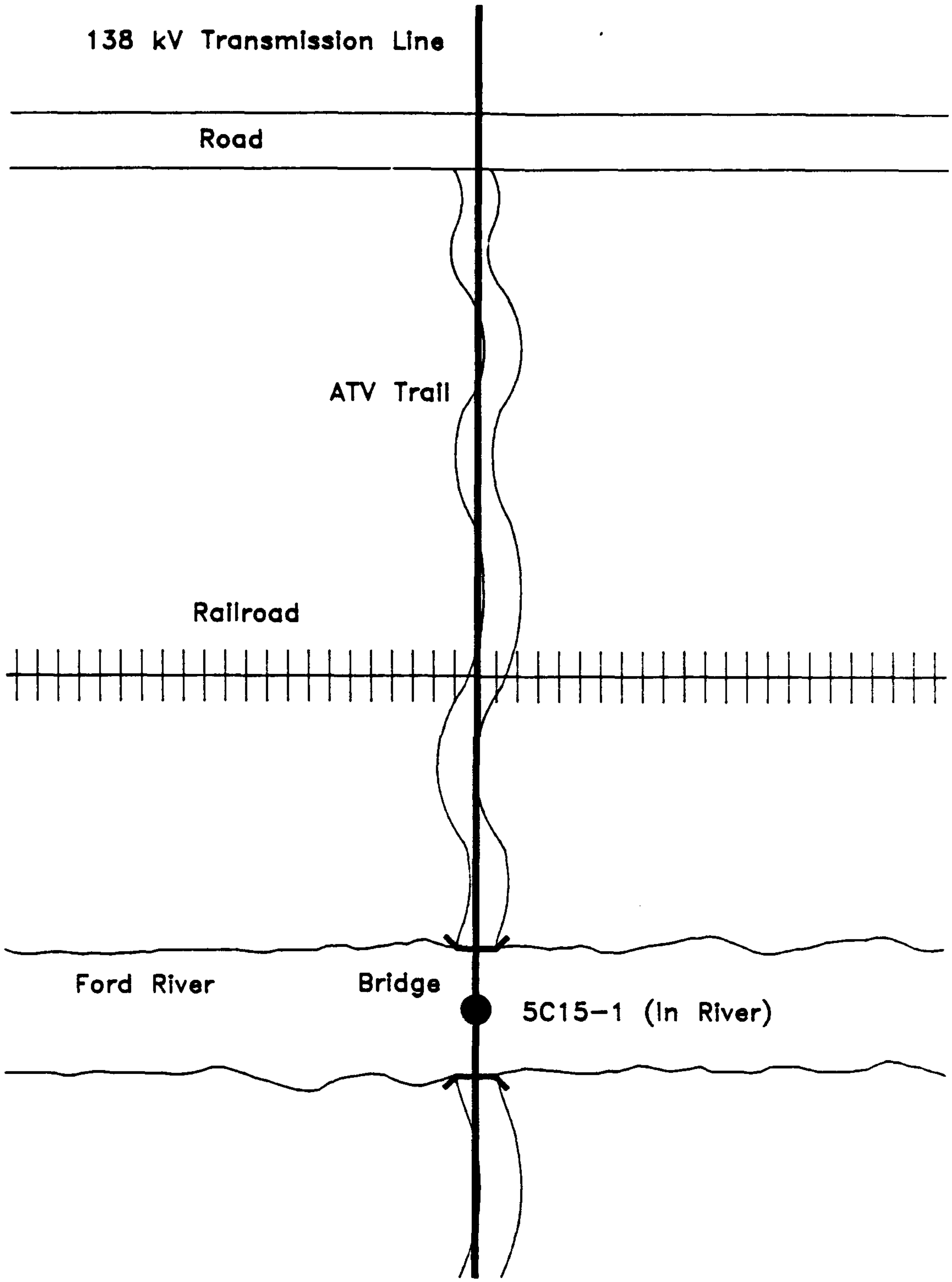


FIGURE E-6. MEASUREMENT POINT AT TRANSMISSION LINE; 5C15-1.

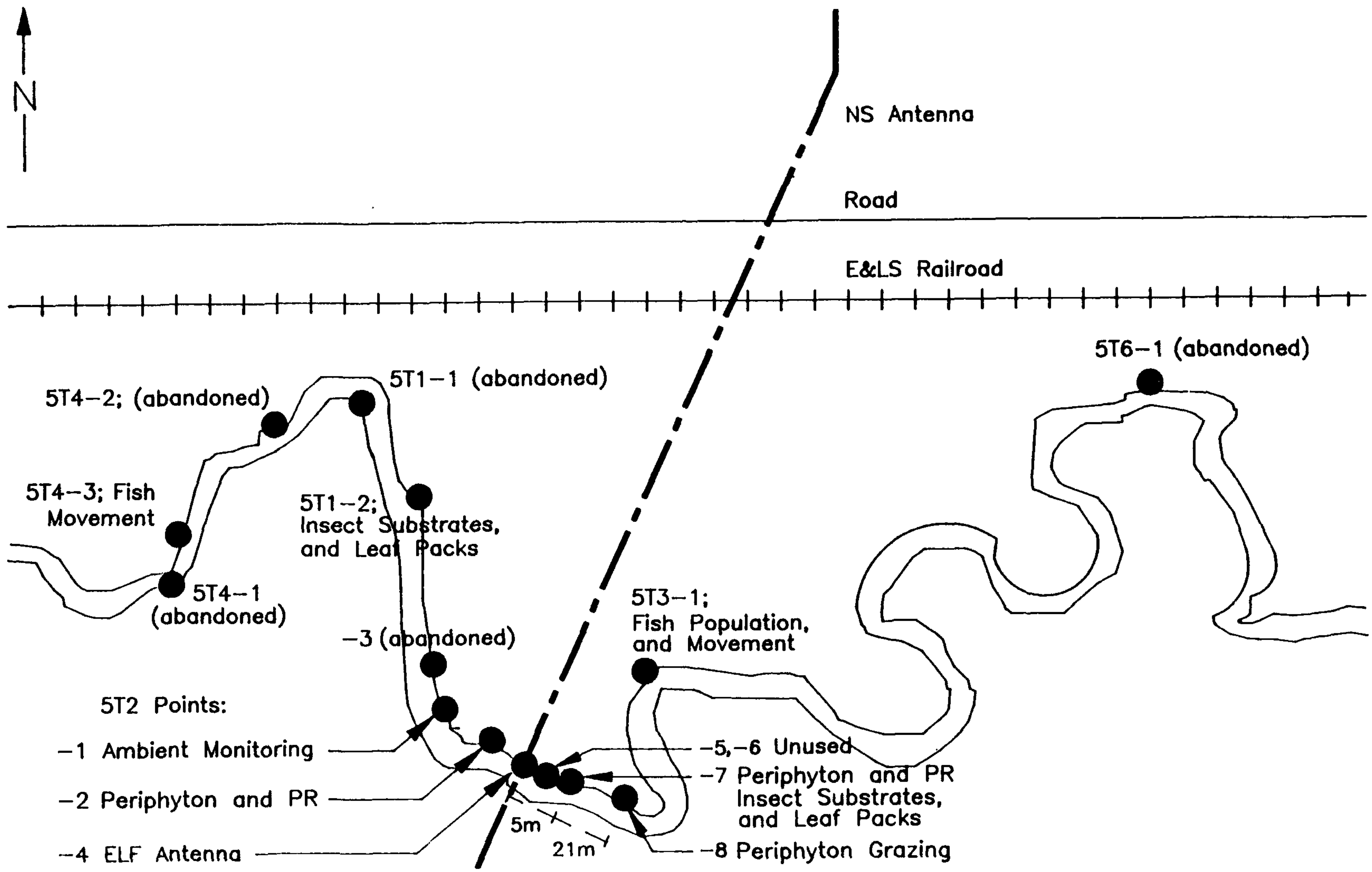


FIGURE E-7. MEASUREMENT POINTS AT FEX; 5T1-1, 2; 5T2-1 THROUGH 8; 5T3-1; 5T4-1, 2; 5T6-1.

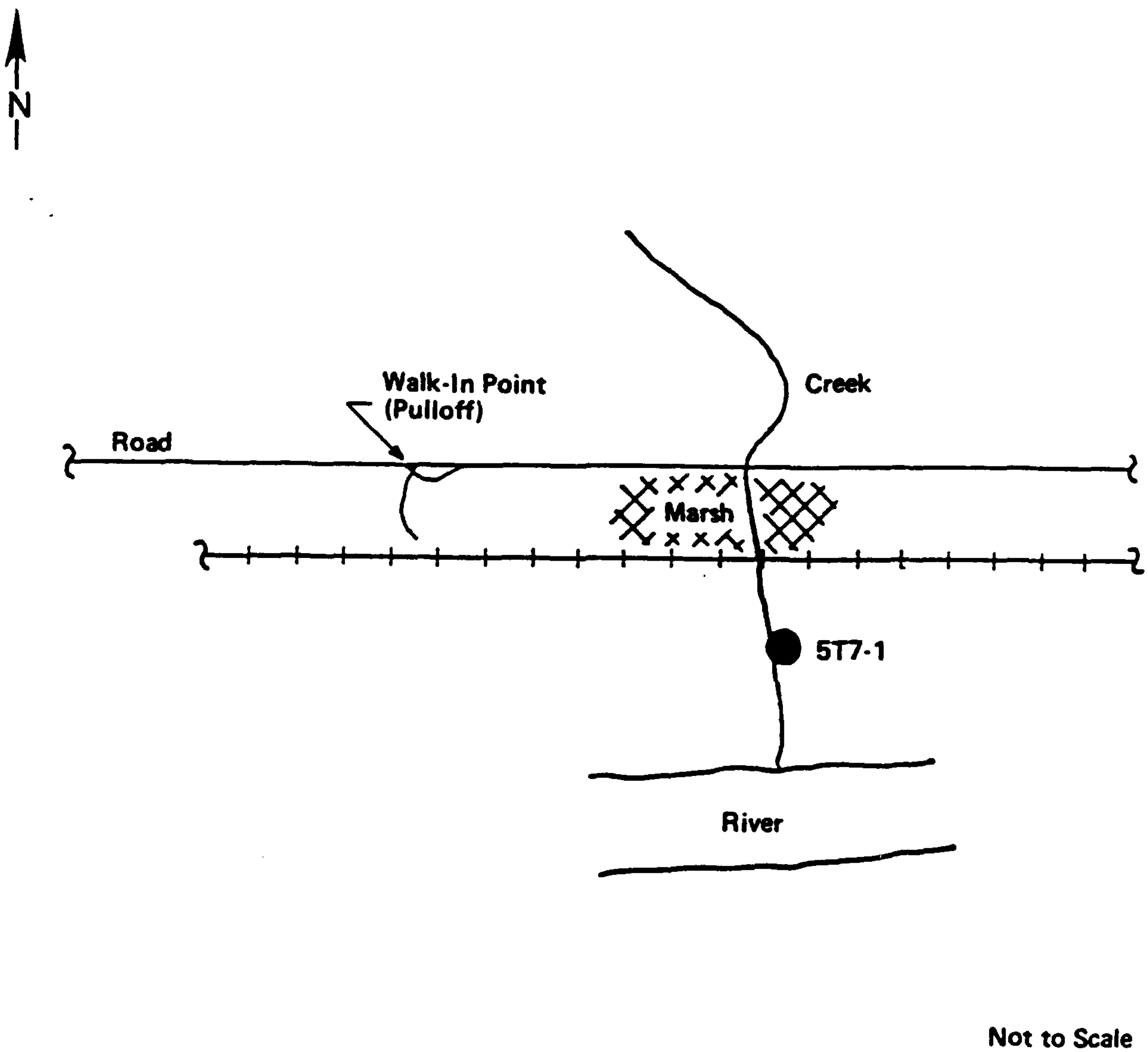


FIGURE E-8. MEASUREMENT POINT AT FEX 7; 5T7-1.

TABLE E-3. 60 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Aquatic Ecosystems Studies

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990[d]	1991[b]
5C1-1	0.002	<0.001	<	<	<	<	<	#	<
5C1-2	<0.001	/	/	<	<	<	<	#	--
5C1-3	<0.001	/	/	<	<	<	<	#	<
5C1-4	-	<0.001	<	<	<	<	<	#	<
5C1-5	-	-	-	-	-	<	<	#	<
5C1-6	-	-	-	-	-	-	<	#	--
5C1-7	-	#	-	-	-	-	-	#	--
5C3-2	<0.001	0.003	<	<	<	<	<	#	<
5C5-1	0.001	<0.001	<	<	<	<	<	#	<
5C14-1	-	0.033	<	<	<	<	<	#	<
5C15-1	-	-	-	-	-	-	6.5	50	32
5T1-1	-	/	/	<	<	<	<	#	--
5T1-2	<0.001	<	<	<	<	<	<	#	<
5T2-1	-	<	<	<	<	<	<0.001	#	<0.001
5T2-2	-	<	<	<	<0.001	0.002	<0.001	#	0.019
5T2-3	-	-	-	<	<	<0.001	<	#	--
5T2-4	-	-	-	-	-	-	-	#	0.065
5T2-5	-	-	-	-	-	-	-	#	--
5T2-6	-	-	-	-	-	-	-	#	--
5T2-7	-	-	-	-	-	-	-	#	0.037
5T2-8	-	-	-	-	-	-	-	#	0.017
5T3-1	-	<	<	<	0.001	<0.001	/	#	<
5T4-1	-	<	/	<	<	<	<	#	--
5T4-2	-	-	-	<	<	<	--	#	--
5T4-3	-	-	-	-	-	-	-	-	<
5T6-1	-	<0.001	<	<	<	<0.001	<	#	--
5T7-1	-	-	-	<	<	<0.001	<	--	--

a = antennas not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 A current.

\- = measurement point not established.
-- = measurement point dropped.
/ = measurement not taken.
\# = measurement precluded by antenna operation.
< = measurement est. <0.001 V/m based on earth E-field.

TABLE E-4. 60 Hz EARTH ELECTRIC FIELD INTENSITES (mV/m)
Aquatic Ecosystems Studies

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990[d]	1991[b]
5C1-1	1.47,1.73	2.7	2.6	0.22	0.26	0.32	0.27	#	0.50
5C1-2	1.8	/	/	0.155	0.160	0.21	0.21	#	--
5C1-3	1.3	/	/	0.126	0.148	0.179	0.22	#	0.32
5C1-4	-	2.5,2.7	2.2	0.174	0.25	0.21	0.44	#	0.085
5C1-5	-	-	-	-	-	0.27	0.33	#	0.43
5C1-6	-	-	-	-	-	-	0.22	#	--
5C1-7	-	-	-	-	-	-	-	#	--
5C3-2	0.049	0.045	0.060	0.119	0.079	0.110	0.110	#	0.50
5C5-1	0.076	0.062	0.059	0.077	0.118	0.140	0.029	#	0.39
5C14-1	-	0.174,0.24	0.22	0.187	0.31	0.41	1.27	#	1.31
5C15-1	-	-	-	-	-	-	1.40	2.2	2.8
5T1-1	0.38	0.38	/	0.125	0.062	0.093	0.26	#	--
5T1-2	0.184	0.154,0.22	0.175	0.037	0.032	0.044	0.048	#	0.111
5T2-1	-	0.22,0.31	0.23	0.057	0.061	0.126	0.037	#	0.166
5T2-2	-	0.26	0.165	0.082	0.076	0.198	0.040	#	0.194
5T2-3	-	-	-	0.050	0.056	0.063	0.033	#	--
5T2-4	-	-	-	-	-	-	-	#	0.26
5T2-5	-	-	-	-	-	-	-	#	--
5T2-6	-	-	-	-	-	-	-	#	--
5T2-7	-	-	-	-	-	-	-	#	0.26
5T2-8	-	-	-	-	-	-	-	#	0.179
5T3-1	-	0.22,0.26	0.23	0.046	0.053	0.115	/	#	0.114
5T4-1	-	0.170,0.195	/	0.032	0.028	0.035	0.099	#	--
5T4-2	-	-	-	0.073	0.048	0.064	--	#	--
5T4-3	-	-	-	-	-	-	-	-	0.107
5T6-1	-	0.37,0.42	0.34	0.047	0.043	0.116	/	#	--
5T7-1	-	-	-	0.040	0.012	0.053	/	--	--

a = antennas not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 A current.

- = measurement point not established.
-- = measurement point dropped.
/ = measurement not taken.
= measurement precluded by antenna operation.

TABLE E-5. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Aquatic Ecosystems Studies

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991
5C1-1	0.008	0.008	0.003	0.001	0.001	0.001	0.001	#	0.001
5C1-2	0.006	/	/	0.001	0.001	<0.001	0.001	#	--
5C1-3	0.004	/	/	0.001	0.001	0.001	0.001	#	0.002
5C1-4	-	0.007,0.008	0.007	0.001	0.001	0.001	0.002	#	0.001
5C1-5	-	-	-	-	-	<0.001	0.001	#	0.003
5C1-6	-	-	-	-	-	-	0.001	#	--
5C1-7	-	-	-	-	-	-	-	#	--
5C3-2	0.003	0.003	0.003	0.005	0.004	0.009	0.008	#	0.029
5C5-1	0.002	0.002	0.002	0.001	0.001	0.002	<0.001	#	0.005
5C14-1	-	0.013,0.021	0.020	0.017	0.094	0.034	0.057	#	0.065
5C15-1	-	-	-	-	-	-	4.4	5.7	11
5T1-1	<0.001	<0.001	/	0.002	0.003	<0.001	0.006	#	--
5T1-2	<0.001	0.001	0.001	0.004	0.005	0.001	0.008	#	0.018
5T2-1	-	0.001,0.002	0.001	0.005	0.009	0.015	0.003	#	0.037
5T2-2	-	0.002	0.001	0.014	0.021	0.047	0.009	#	0.103
5T2-3	-	-	-	0.004	0.007	0.007	0.003	#	--
5T2-4	-	-	-	-	-	-	-	#	0.157
5T2-5	-	-	-	-	-	-	-	#	--
5T2-6	-	-	-	-	-	-	-	#	--
5T2-7	-	-	-	-	-	-	-	#	0.133
5T2-8	-	-	-	-	-	-	-	#	0.083
5T3-1	-	0.001,0.002	0.001	0.005	0.009	0.021	/	#	0.031
5T4-1	-	0.001	/	<0.001	0.002	<0.001	0.004	#	--
5T4-2	-	-	-	0.001	0.002	<0.001	--	#	--
5T4-3	-	-	-	-	-	-	-	-	0.009
5T6-1	-	0.001	0.001	0.001	0.002	0.003	/	--	--
5T7-1	-	-	-	0.001	0.001	0.005	/	#	--

a = antennas not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 A current.

\- = measurement point not established.
-- = measurement point dropped.
/ = measurement not taken.
= measurement precluded by antenna operation.

TABLE E-6. 76 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Aquatic Ecosystems Studies

Site No., Meas. Pt.	1986 NS 4 A	1986 NEW 6 A	1986 SEW 6 A	1986 SEW 10 A, EX	1987 NS 15 A	1987 EW 15 A	1988 NS 75 A	1988 EW 75 A	1989 B 150 A	1990 B 150 A	1991 NS 150 A
5C1-1	<	<	<	*	<	<	<	<	<	<	<
5C1-2	<	<	<	*	<	<	<	<	<	--	--
5C1-3	<	<	<	*	<	<	<	<	<	<	<
5C1-4	<	<	<	*	<	<	<	<	<	<	<
5C1-5	-	-	-	-	-	-	<	<	<	<	<
5C1-6	-	-	-	-	-	-	-	-	<	--	--
5C1-7	-	-	-	-	-	-	-	-	-	<	--
5C3-2	<	<	<	*	<	<	<	<	<	<	<
5C5-1	<	<	<	*	<	<	<	<	<	<	<
5C14-1	<	<	<	*	<	<	<	<	<	<	<
5C15-1	-	-	-	-	-	-	-	-	#	#	#
5T1-1	<	<	<	*	0.009	<	0.037	0.001	0.091	--	--
5T1-2	<	<	<	*	<0.001	<	0.014	0.002	0.029	0.042	0.035
5T2-1	0.001	<	<	*	0.005	<	0.026	0.002	0.062	/	0.048
5T2-2	0.011	<	<	*	0.022	<0.001	0.130	<0.001	0.54	0.27	1.02
5T2-3	<	<	<	*	0.005	<	0.030	<0.001	0.049	--	--
5T2-4	-	-	-	-	-	-	-	-	-	9.8	4.0
5T2-5	-	-	-	-	-	-	-	-	-	8.3	--
5T2-6	-	-	-	-	-	-	-	-	-	8.3	--
5T2-7	-	-	-	-	-	-	-	-	-	6.7	2.8
5T2-8	-	-	-	-	-	-	-	-	-	1.08	1.51
5T3-1	0.008	<	<	*	0.020	<	0.104	<0.001	0.175	0.24	0.165
5T4-1	<	<	<	*	0.003	<	0.014	<0.001	0.036	--	--
5T4-2	<	<	<	*	0.007	<	0.054	<0.001	--	0.088	--
5T4-3	-	-	-	-	-	-	-	-	-	-	0.033
5T6-1	<	<	<	*	0.006	<	0.035	0.002	0.057	--	--
5T7-1	<	<	<	*	/	<	0.014	<0.001	0.029	--	--

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.
A = amperes.

- = measurement point not established.
-- = measurement point dropped.
/ = measurement not taken.
< = measurement est. <0.001 based on earth E-field.
* = data cannot be extrapolated.
# = measurement precluded by ambient 60 Hz fields.

TABLE E-7. 76 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Aquatic Ecosystems Studies

Site No., Meas. Pt.	1986 NS 4 A	1986 NEW 6 A	1986 SEW 6 A	1986 SEW 10 A, EX	1987 NS 15 A	1987 EW 15 A	1988 NS 75 A	1988 EW 75 A	1989 B 150 A	1990 B 150 A	1991 NS 150 A
5C1-1	0.33	0.020	0.052	0.087	1.33	0.158	6.8	0.81	11.7	12.5	10.6
5C1-2	0.24	0.016	0.053	0.088	1.07	0.186	4.9	0.76	9.9	--	--
5C1-3	0.191	0.013	0.047	0.078	0.85	0.130	4.1	0.73	7.6	8.0	7.0
5C1-4	0.26	0.014	0.075	0.125	1.02	0.160	4.6	0.64	10.5	10.5	7.3
5C1-5	-	-	-	-	-	-	7.1	0.83	11.9	12.3	11.5
5C1-6	-	-	-	-	-	-	-	-	7.7	--	--
5C1-7	-	-	-	-	-	-	-	-	-	7.9	--
5C3-2	0.013	0.002	0.007	0.012	0.067	0.023	0.26	0.091	0.58	0.61	0.59
5C5-1	0.034	0.002	0.009	0.015	0.138	0.035	0.68	0.150	1.39	1.51	1.37
5C14-1	0.042	0.004	0.015	0.025	0.183	0.055	0.81	0.25	1.86	1.70	1.47
5C15-1	-	-	-	-	-	-	-	-	#	#	1.37
5T1-1	2.5	0.080	0.108	0.180	7.5	0.33	46	1.47	98	--	--
5T1-2	0.77	0.034	0.097	0.162	2.9	0.30	16.1	1.61	27	32	30
5T2-1	1.33	0.045	0.077	0.128	5.4	0.22	25	1.16	47	48	45
5T2-2	1.62	0.052	0.067	0.112	6.1	0.184	31	0.100	65	61	55
5T2-3	1.17	0.042	0.079	0.132	4.9	0.23	21	1.18	40	--	--
5T2-4	-	-	-	-	-	-	-	-	-	59	64
5T2-5	-	-	-	-	-	-	-	-	-	61	--
5T2-6	-	-	-	-	-	-	-	-	-	73	--
5T2-7	-	-	-	-	-	-	-	-	-	85	71
5T2-8	-	-	-	-	-	-	-	-	-	95	77
5T3-1	1.22	0.045	0.082	0.137	4.8	0.27	18.8	1.07	45	42	48
5T4-1	0.75	0.026	0.061	0.102	3.0	0.182	17.3	1.06	35	--	--
5T4-2	1.91	0.056	0.077	0.128	5.3	0.21	37	1.06	--	66	--
5T4-3	-	-	-	-	-	-	-	-	-	-	36
5T6-1	1.21	0.030	0.066	0.110	4.5	0.20	24	0.96	45	--	--
5T7-1	0.76	0.033	0.072	0.120	2.6	0.189	15.3	1.09	9.4	--	--

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
A = amperes.
EX = extrapolated data.
\- = measurement point not established.
-- = measurement point dropped.
/ = data not taken.
\# = measurement precluded by ambient 60 Hz fields.

TABLE E-8. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Aquatic Ecosystems Studies

Site No., Meas. Pt.	1986				1987		1988		1989	1990	1991
	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	NS 150 A
5C1-1	0.001	<0.001	<0.001	*	0.005	0.001	0.022	0.005	0.039	·0.036	0.042
5C1-2	0.001	<0.001	<0.001	*	0.005	0.001	0.022	0.005	0.038	--	--
5C1-3	0.001	<0.001	<0.001	*	0.005	0.001	0.022	0.005	0.038	0.035	0.043
5C1-4	0.001	<0.001	<0.001	*	0.005	0.001	0.022	0.005	0.040	0.037	0.043
5C1-5	-	-	-	-	-	-	0.022	0.005	0.038	0.035	0.045
5C1-6	-	-	-	-	-	-	-	-	0.038	--	--
5C1-7	-	-	-	-	-	-	-	-	-	0.035	--
5C3-2	0.001	<0.001	<0.001	*	0.003	0.001	0.016	0.004	0.038	0.037	0.033
5C5-1	0.003	<0.001	0.001	0.002	0.013	0.002	0.061	0.007	0.138	0.125	0.115
5C14-1	0.001	<0.001	<0.001	*	0.005	0.001	0.024	0.004	0.060	0.053	0.059
5C15-1	-	-	-	-	-	-	-	-	#	#	0.20
5T1-1	0.045	0.001	<0.001	*	0.170	0.002	0.81	0.006	1.79	--	--
5T1-2	0.063	0.002	<0.001	*	0.25	0.002	1.19	0.006	2.3	2.3	2.2
5T2-1	0.129	0.004	0.001	0.002	0.50	0.002	2.3	0.008	4.8	4.8	4.4
5T2-2	0.31	0.009	0.001	0.002	1.20	0.003	5.5	0.018	12.7	10.6	13.5
5T2-3	0.110	0.003	<0.001	*	0.41	0.002	1.90	0.007	3.7	--	--
5T2-4	-	-	-	-	-	-	-	-	-	22	21
5T2-5	-	-	-	-	-	-	-	-	-	22	--
5T2-6	-	-	-	-	-	-	-	-	-	22	--
5T2-7	-	-	-	-	-	-	-	-	-	21	19.9
5T2-8	-	-	-	-	-	-	-	-	-	12	14
5T3-1	0.137	0.004	0.001	0.002	0.51	0.001	2.6	0.014	5.1	4.7	4.9
5T4-1	0.028	0.001	<0.001	*	0.118	0.002	0.58	0.007	1.17	--	--
5T4-2	0.033	0.001	<0.001	*	0.123	0.002	0.60	0.006	--	1.22	--
5T4-3	-	-	-	-	-	-	-	-	-	-	1.06
5T6-1	0.029	0.001	0.001	0.002	0.109	0.002	0.51	0.008	1.03	--	--
5T7-1	0.011	<0.001	0.001	0.002	0.040	0.002	0.20	0.008	0.40	--	--

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
A = amperes.

EX = extrapolated data.
- = measurement point not established.
-- = measurement point dropped.
/ = data not taken.
* = data cannot be extrapolated.
# = measurement precluded by ambient 60 Hz fields.

APPENDIX F

SOIL AMOEBA STUDIES

SOIL AMOEBA STUDIES

The objectives of the soil amoeba studies are to monitor population and species characteristics, cell cycle, cropping efficiency, and distribution in the soil. The electric and magnetic fields in the earth are considered the most important electromagnetic (EM) factors to be examined. The electric field in the air is not expected to have a significant impact on the objectives of these studies.

IITRI field crews made ELF EM field measurements at nine measurement points within the two treatment sites and single control site for the soil amoeba studies in 1991. The study sites and the measurement points within those sites were unchanged from 1991. Measurement dates for 1991 and previous years appear in Table F-1.

TABLE F-1. EM FIELD MEASUREMENT DATES
Soil Amoeba Studies

Year	Measurement Dates	
1983	Jun 9, 10, 15	
1984	May 14	Aug 10, 13, 15
1985	May 6	Jul 16, 23
1986	Oct 3, 10, 16	
1987	Sep 30	Oct 1, 2
1988	Sep 20, 23, 27	Oct 25
1989	Sep 11, 18, 20	
1990	Sep 27	Oct 3, 9
1991	Sep 24, 25, 27	Oct 2

The positions of the study sites relative to the NRTF-Republic are shown on the composite map in Figure F-1. The site numbers listed on the map are those used by IITRI. Table F-2 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites. Details of measurement locations within sites are shown in Figures F-2 through F-4.

EM field measurements for 1991 and previous years are found in Tables F-3 through F-8. Tables F-3, F-4, and F-5 present 60 Hz data for the air electric field, earth electric field, and magnetic flux density, respectively. Tables F-6, F-7, and F-8 present 76 Hz data for these fields as well as the corresponding operating currents of the NRTF-Republic for each year.

TABLE F-2. SITE NUMBER CROSS-REFERENCE
Soil Amoeba Studies

IITRI Site No.	Investigator's Site Name	Location Township	Location Range	Location Section(s)
6T3	Leeman's Road	T43N	R29W	23
6T4	Wells Grade Ground	T42N	R29W	2
6C2	Merriman Truck Road Control	T41N	R29W	21

Considerable year-to-year variability in the 60 Hz fields is evident. The primary factors in this variability at treatment sites are changes in power line loading conditions (which are unknown) and differences in the configuration of the antennas at the time of measurement. Notes on the antenna configurations are included in the tables primarily for engineering use. The 60 Hz measurements at treatment sites in 1986-1991 (excluding 1989) were taken while the antennas were off, and are representative of 60 Hz levels present during maintenance periods. In 1989, measurements were taken at the ground site during full-power operation of the antennas with an unmodulated signal. These values indicate that 60 Hz EM fields present during operation of the antennas are comparable to those present when the antennas are off.

Annual variations in the 60 Hz EM fields measured at the control study site are also caused by differences in power line loading, but are not dependent on the antennas or their configuration because of the distance of this site from the antennas. The 60 Hz EM field values at the control site, nonetheless, are about as variable as those at the treatment sites.

Overall, the 60 Hz EM fields measured at all study sites in 1991 are consistent with previous field values and with the expected differences in power line loads and the antenna configuration. Regardless of the field variability associated with the measurement condition, 76 Hz EM fields at the treatment sites consistently dominate the 60 Hz EM fields at treatment and control sites, and the ratios of 60 Hz EM fields between matched treatment/control sites continue to meet exposure criteria guidelines established at the beginning of the study.

The 76 Hz EM field measurements in 1991 were made with 150 ampere antenna currents, the predominant operating current of the NRTF-Republic since 4 May 1989. The antenna currents at which measurements were made in each year are given in the column headings of Tables F-6 through F-8. The annual increases in field magnitudes reflect the level of antenna current at the time of measurement: 4 or 6 amperes in 1986, 15 amperes in 1987, 75 amperes in 1988, and 150 amperes in 1989, 1990, and 1991. The 1991 measurements are consistent with the 1989 and 1990 measurements at the same current, and are proportional to the 1986, 1987, and 1988 measurements made at lower currents.

Plots of growth chamber data collected by data loggers during 1988-1991 field seasons are presented in Figures F-5 through F-16. Each figure presents data for the four field seasons for each chamber. Only current densities are presented for the matched current density chambers and electric fields for the matched electric field chambers although both fields are measured for each chamber. The figures illustrate the graduation of EM exposure as the NRTF-Republic progressed through various stages before reaching full power operation in 1989.

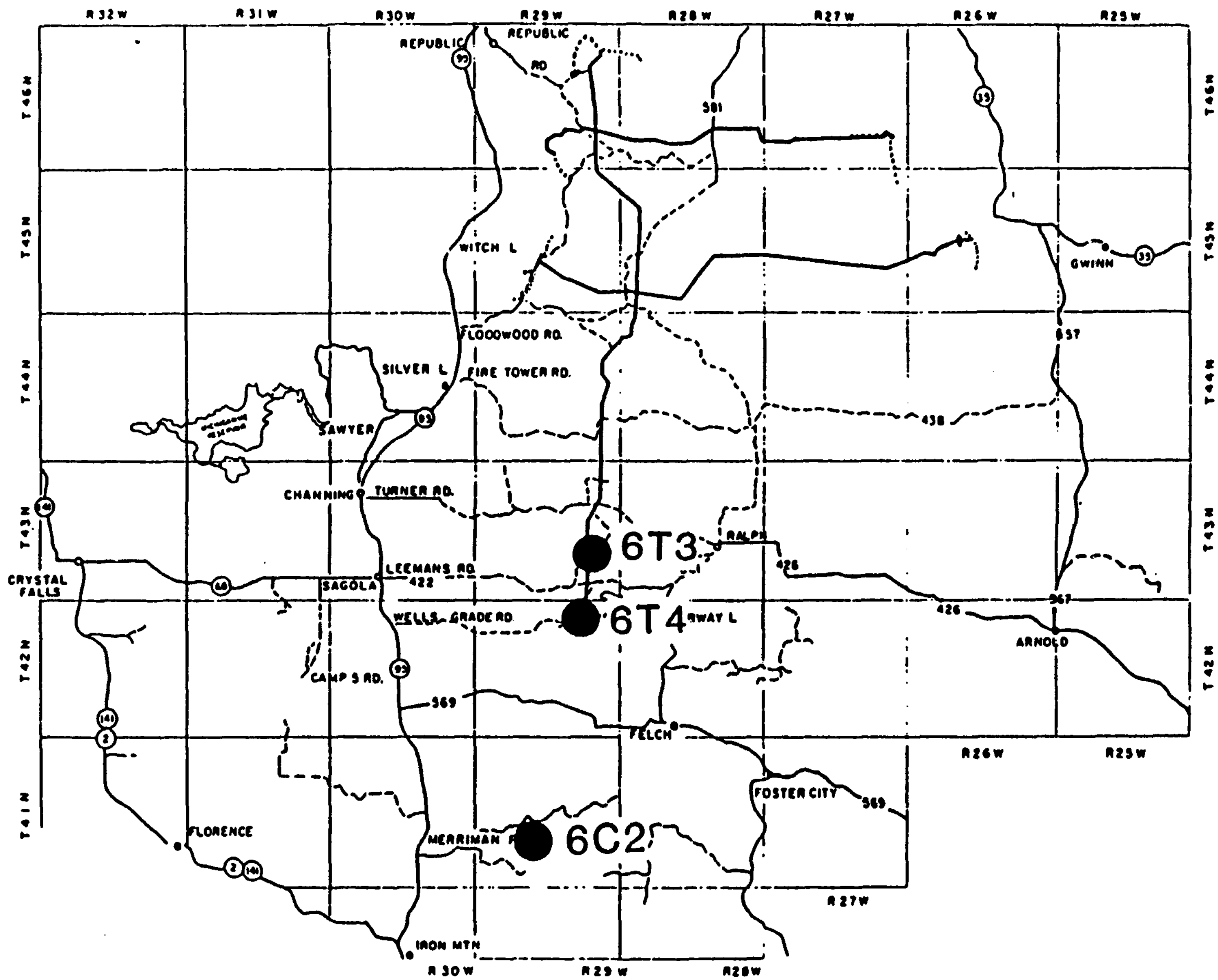


FIGURE F-1. POSITIONS OF SOIL AMOEBA STUDY SITES RELATIVE TO NRTF-REPUBLIC ANTENNA ELEMENTS.

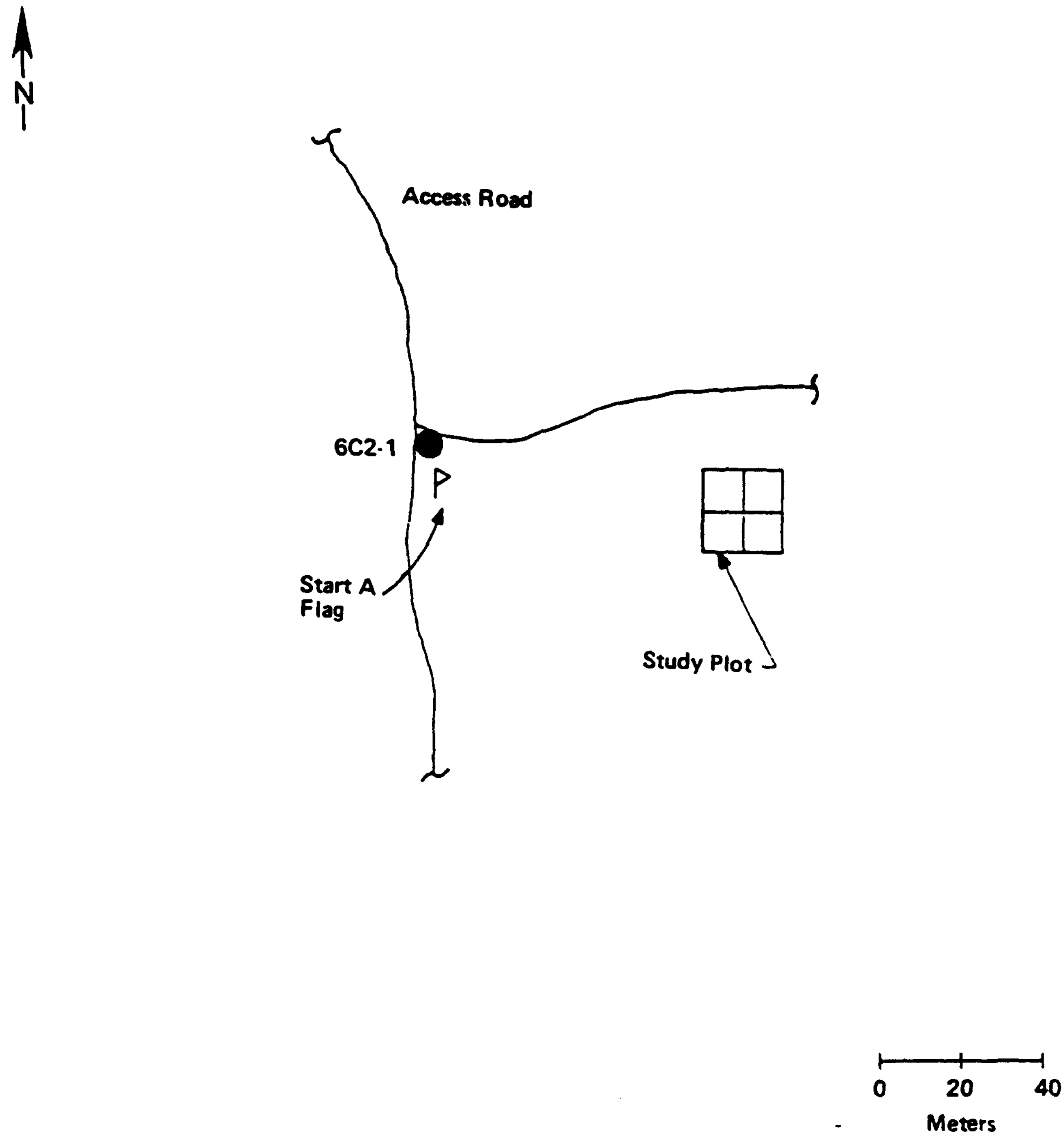


FIGURE F-2. MEASUREMENT POINT AT MERRIMAN TRUCK ROAD CONTROL; 6C2-1.

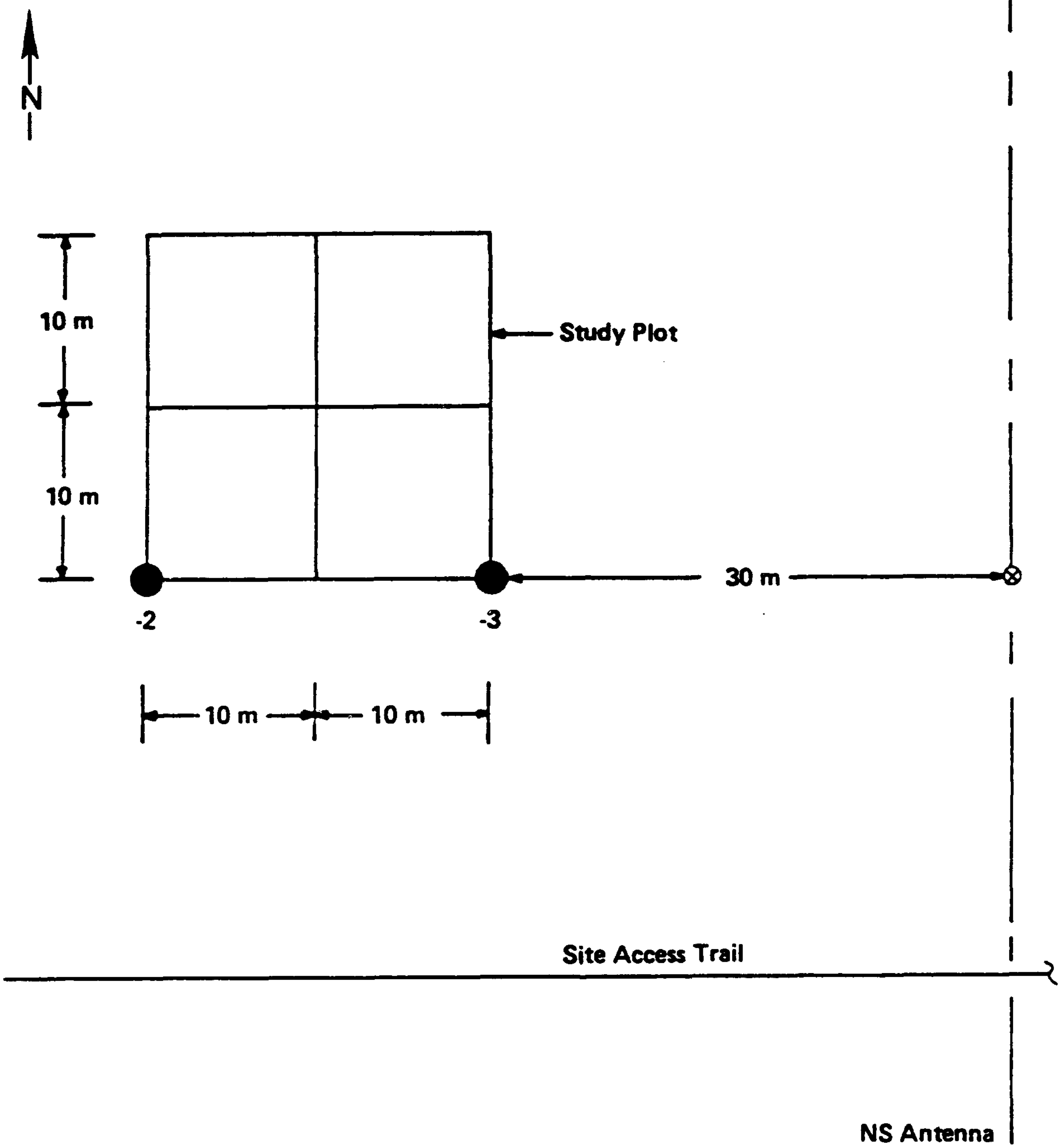
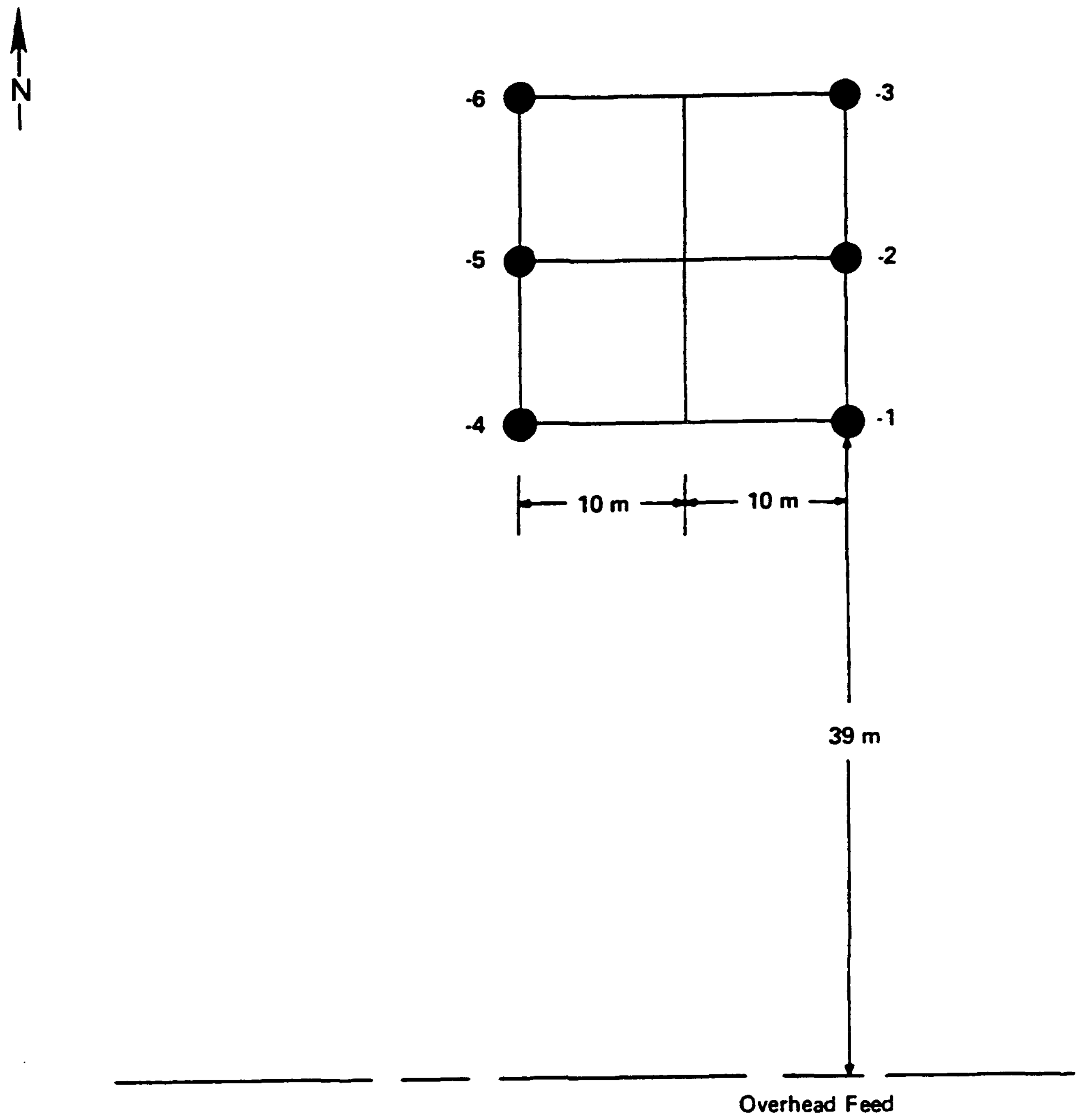


FIGURE F-3. MEASUREMENT POINTS AT LEEMAN'S ROAD; 6T3-2, 3.

60297/790



FIGU F-4. MEASUREMENT POINTS AT WELLS GRADE GROUND; 6T4-1 THROUGH 6.

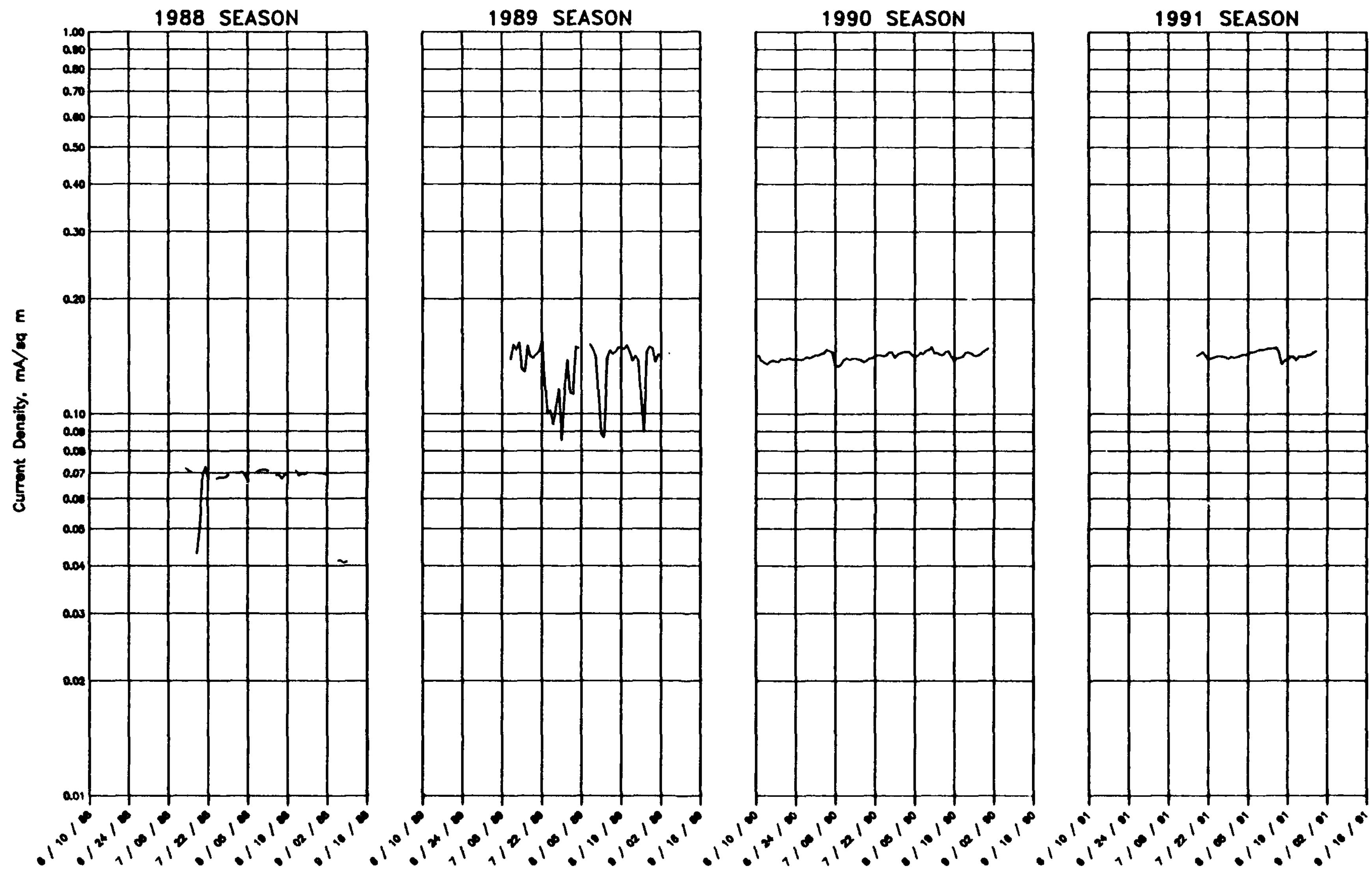


FIGURE F-5. DAILY AVERAGE CURRENT DENSITIES FOR CHAMBER 1 AT THE SOIL AMOEBA ANTENNA STUDY SITE.

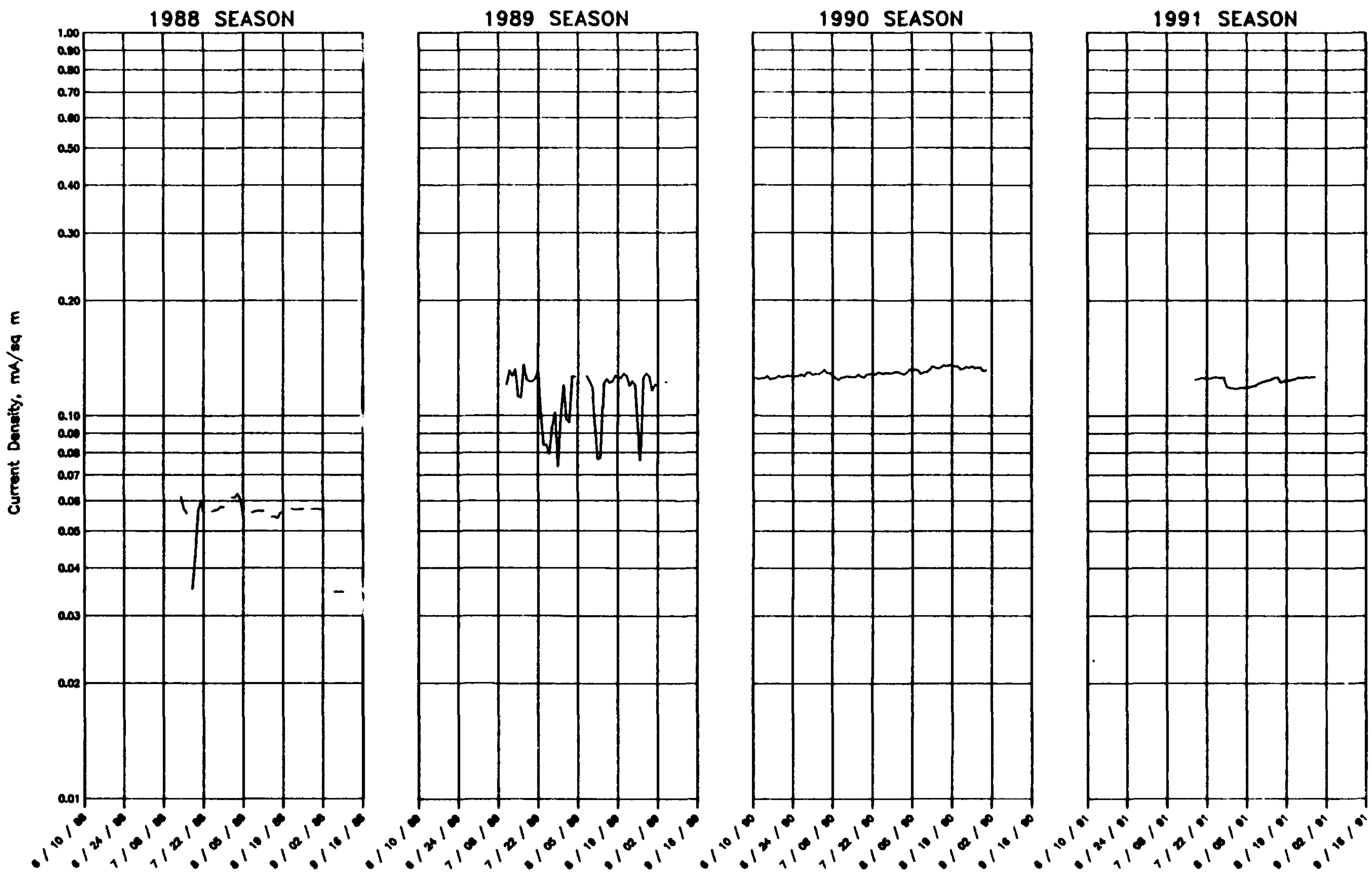


FIGURE F-6. DAILY AVERAGE CURRENT DENSITIES FOR CHAMBER 2 AT THE SOIL AMOEBA ANTENNA STUDY SITE.

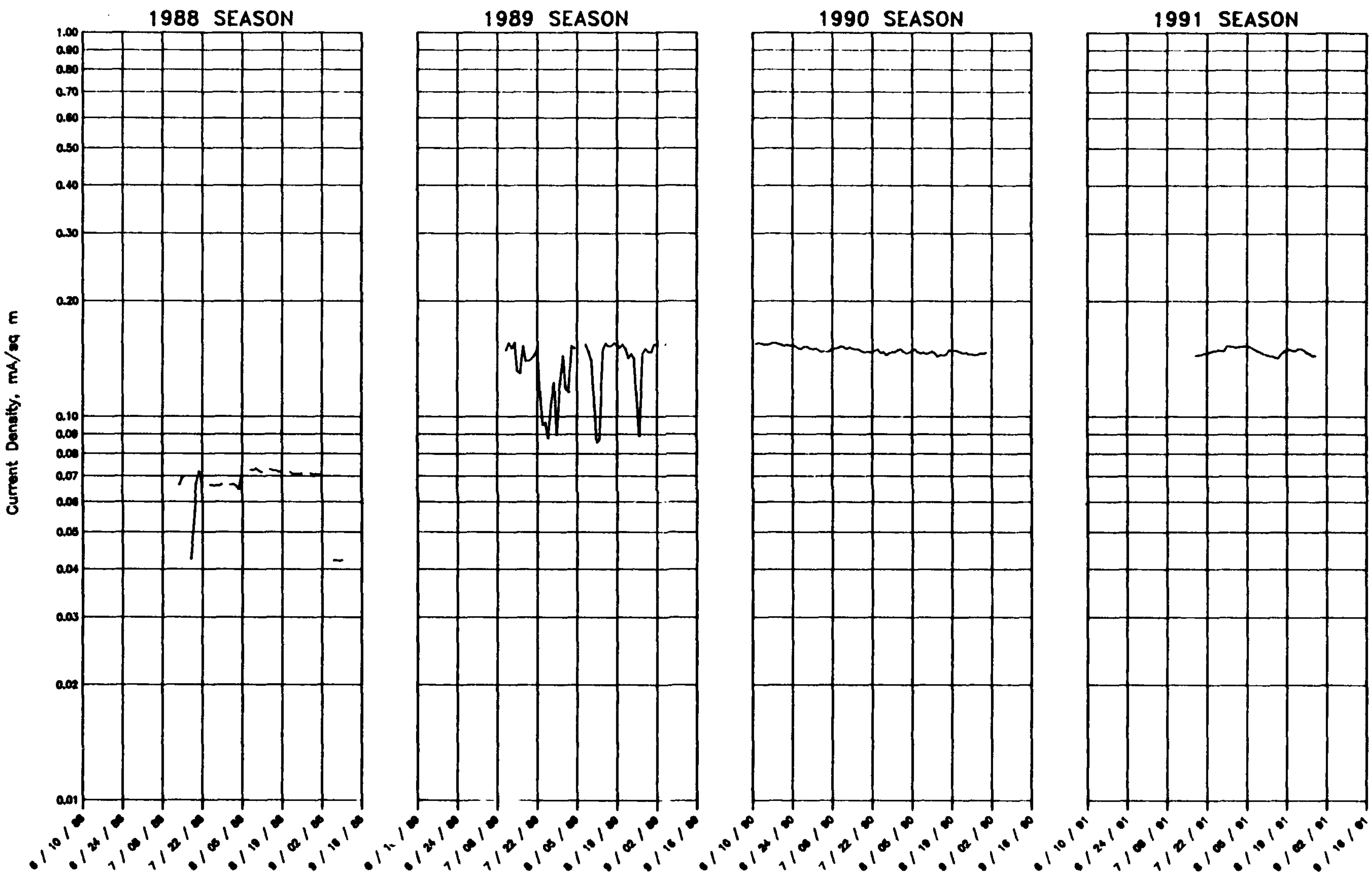


FIGURE F-7. DAILY AVERAGE CURRENT DENSITIES FOR CHAMBER 3 AT THE SOIL AMOEBA ANTENNA STUDY SITE.

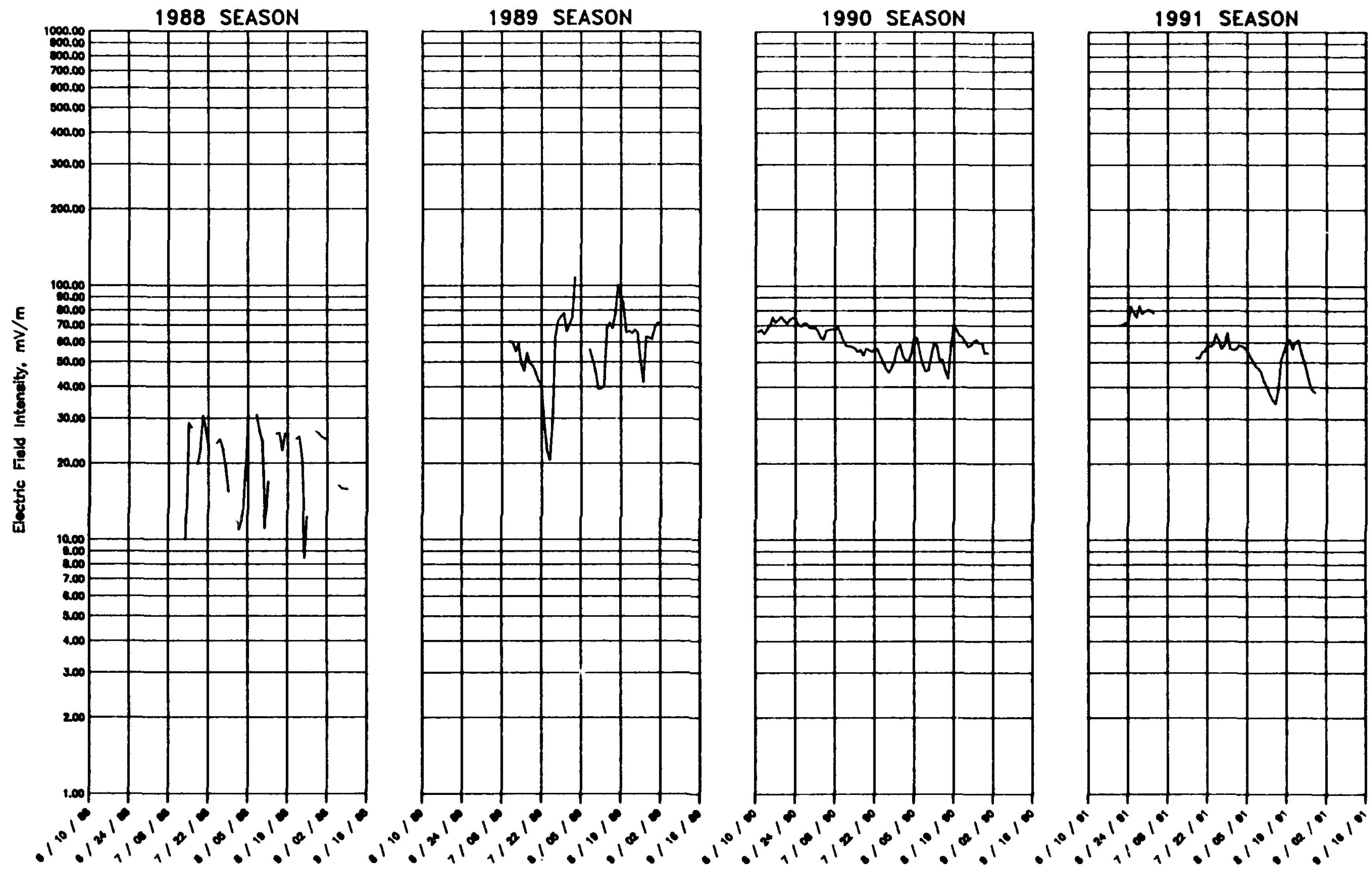


FIGURE F-8. DAILY AVERAGE ELECTRIC FIELD INTENSITIES FOR CHAMBER 4 AT THE SOIL AMOEBA ANTENNA STUDY SITE.

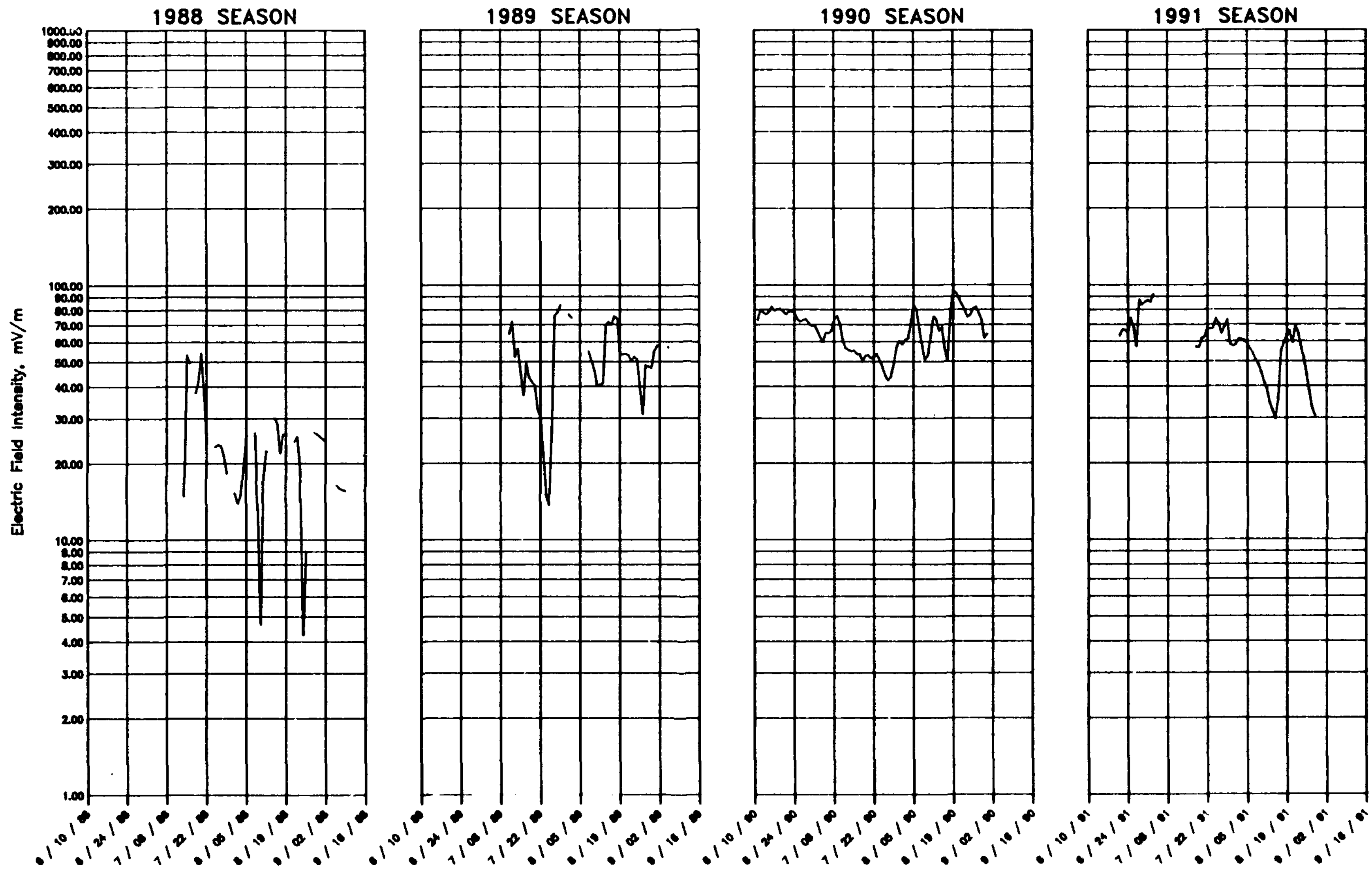


FIGURE F-9. DAILY AVERAGE ELECTRIC FIELD INTENSITIES FOR CHAMBER 5 AT THE SOIL AMOEBA ANTENNA STUDY SITE.

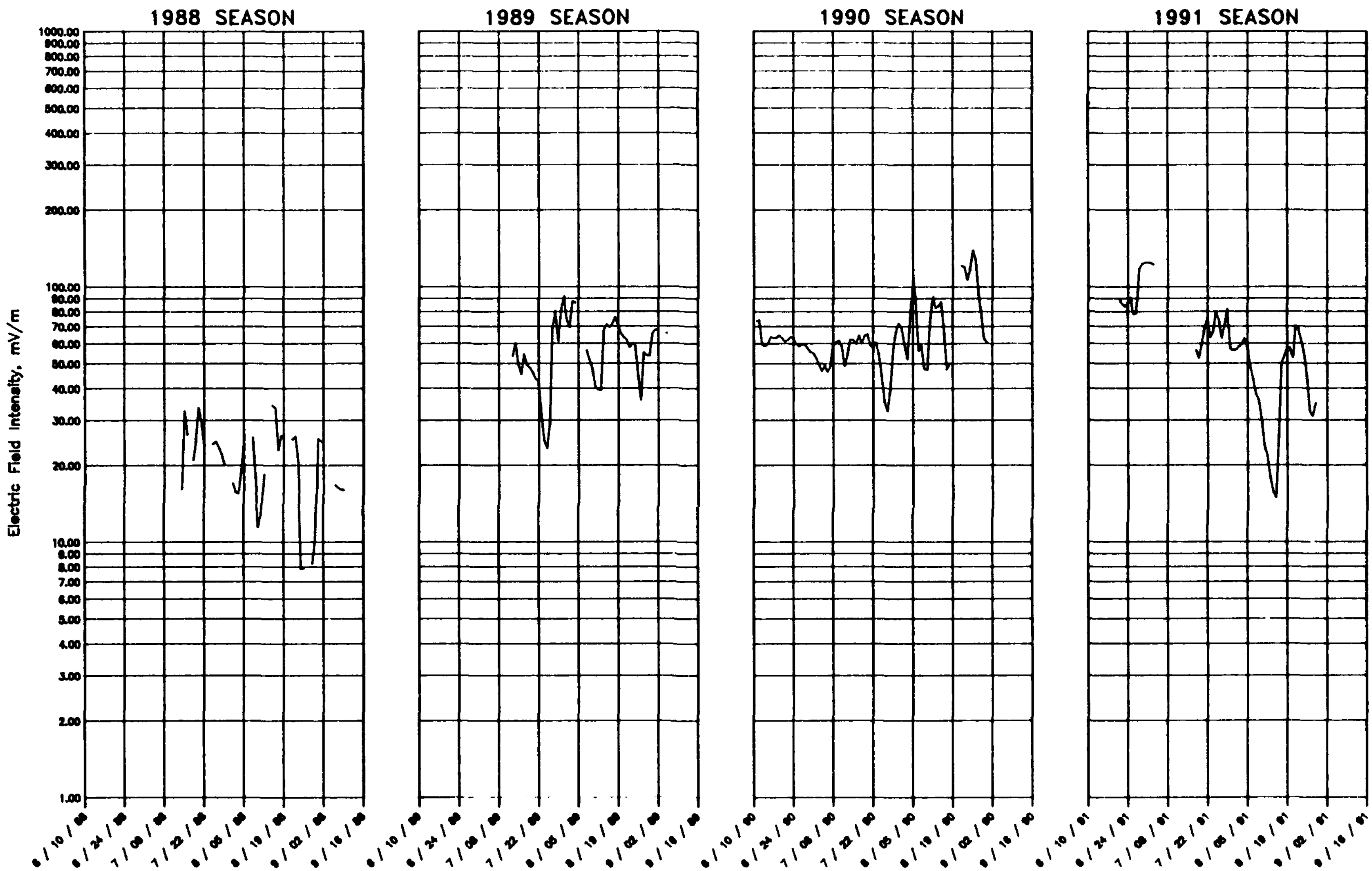


FIGURE F-10. DAILY AVERAGE ELECTRIC FIELD INTENSITIES FOR CHAMBER 6 AT THE SOIL AMOEBA ANTENNA STUDY SITE.

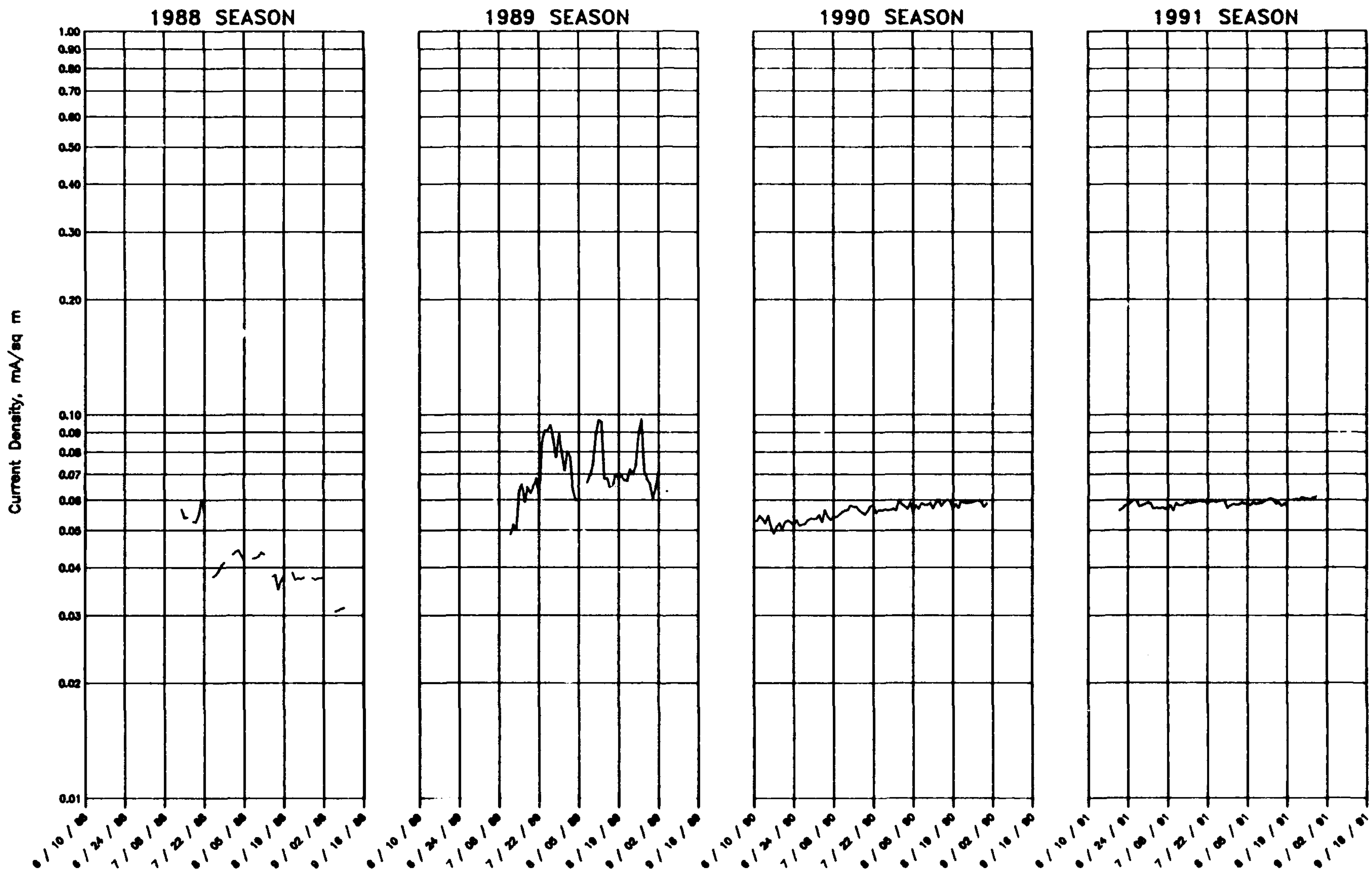


FIGURE F-11. DAILY AVERAGE ELECTRIC FIELD INTENSITIES FOR CHAMBER 1 AT THE SOIL AMOEBA GROUND STUDY SITE.

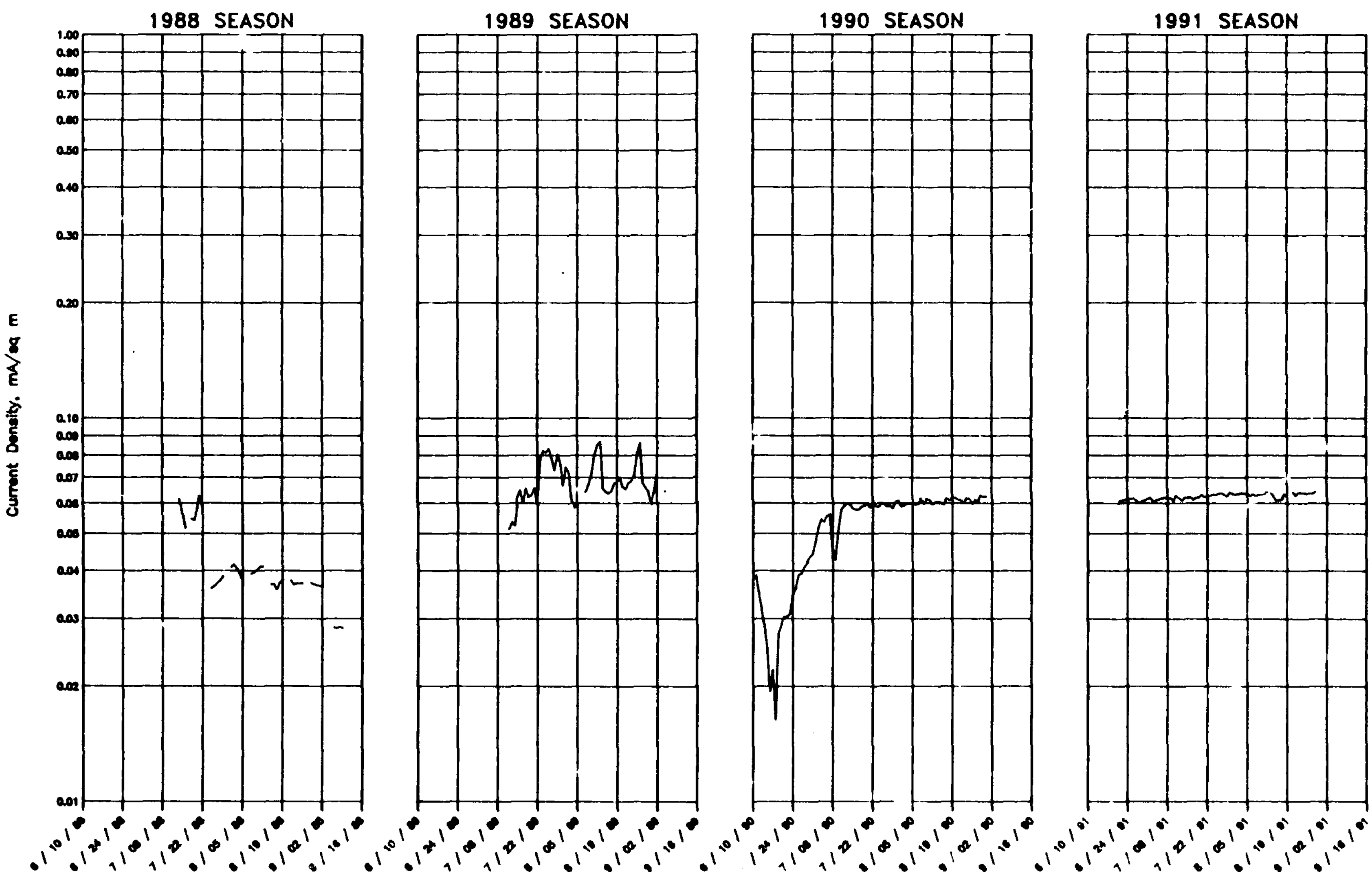


FIGURE F-12. DAILY AVERAGE CURRENT DENSITIES FOR CHAMBER 2 AT THE SOIL AMOEBA GROUND STUDY SITE.

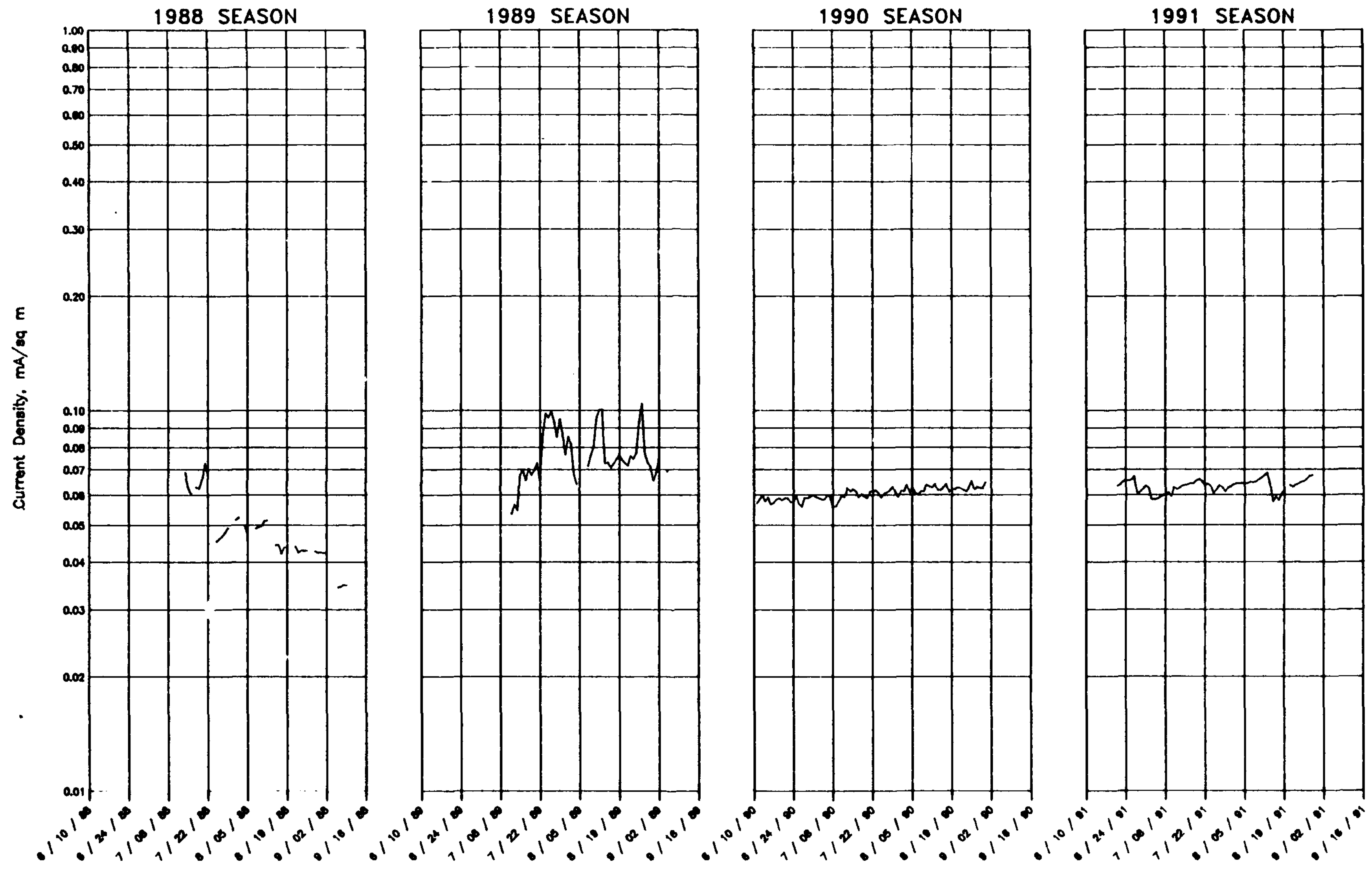


FIGURE F-13. DAILY AVERAGE CURRENT DENSITIES FOR CHAMBER 3 AT THE SOIL AMOEBA GROUND STUDY SITE.

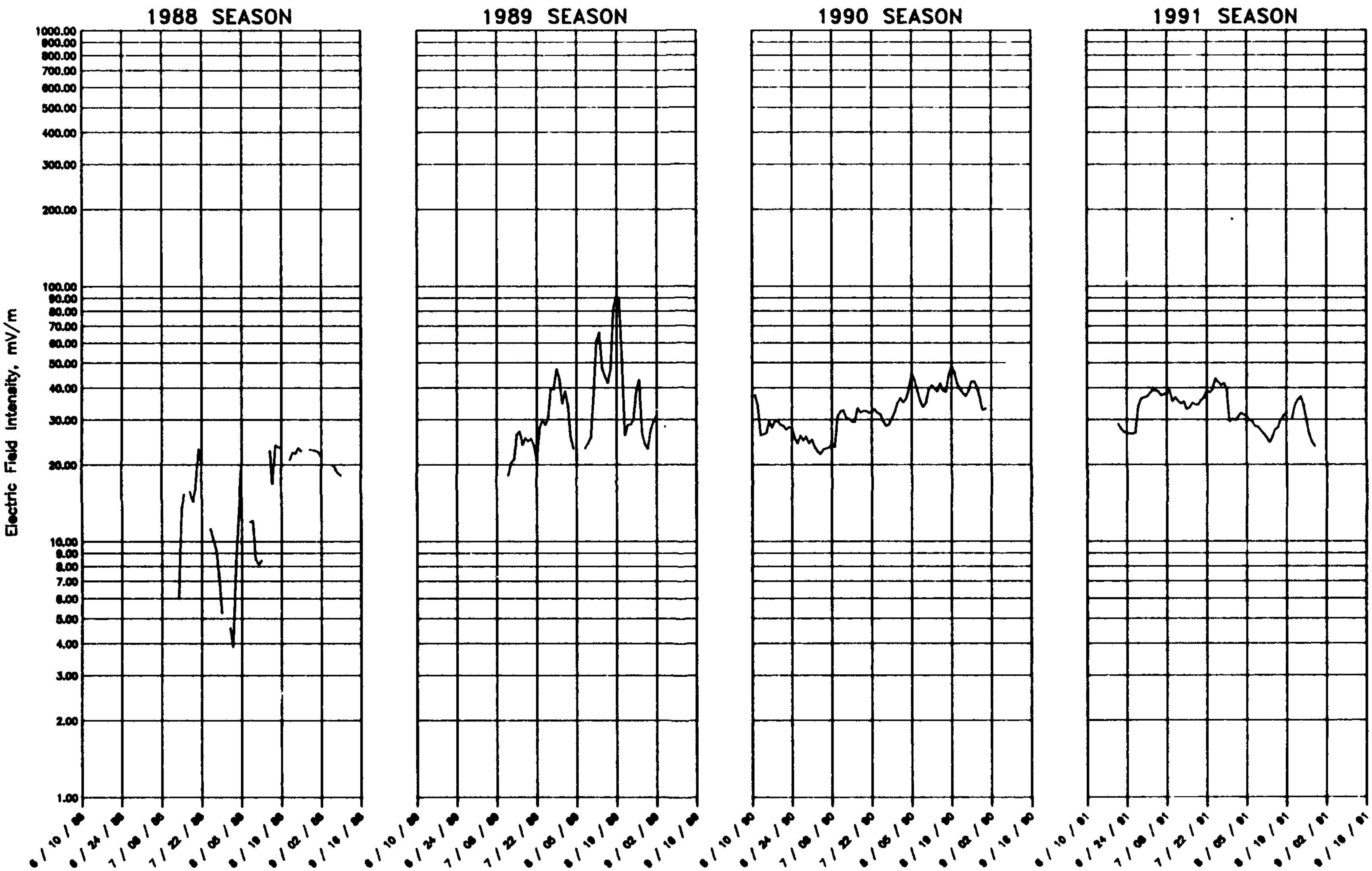


FIGURE F-14. DAILY AVERAGE ELECTRIC FIELD INTENSITIES FOR CHAMBER 4 AT THE SOIL AMOEBA GROUND STUDY SITE.

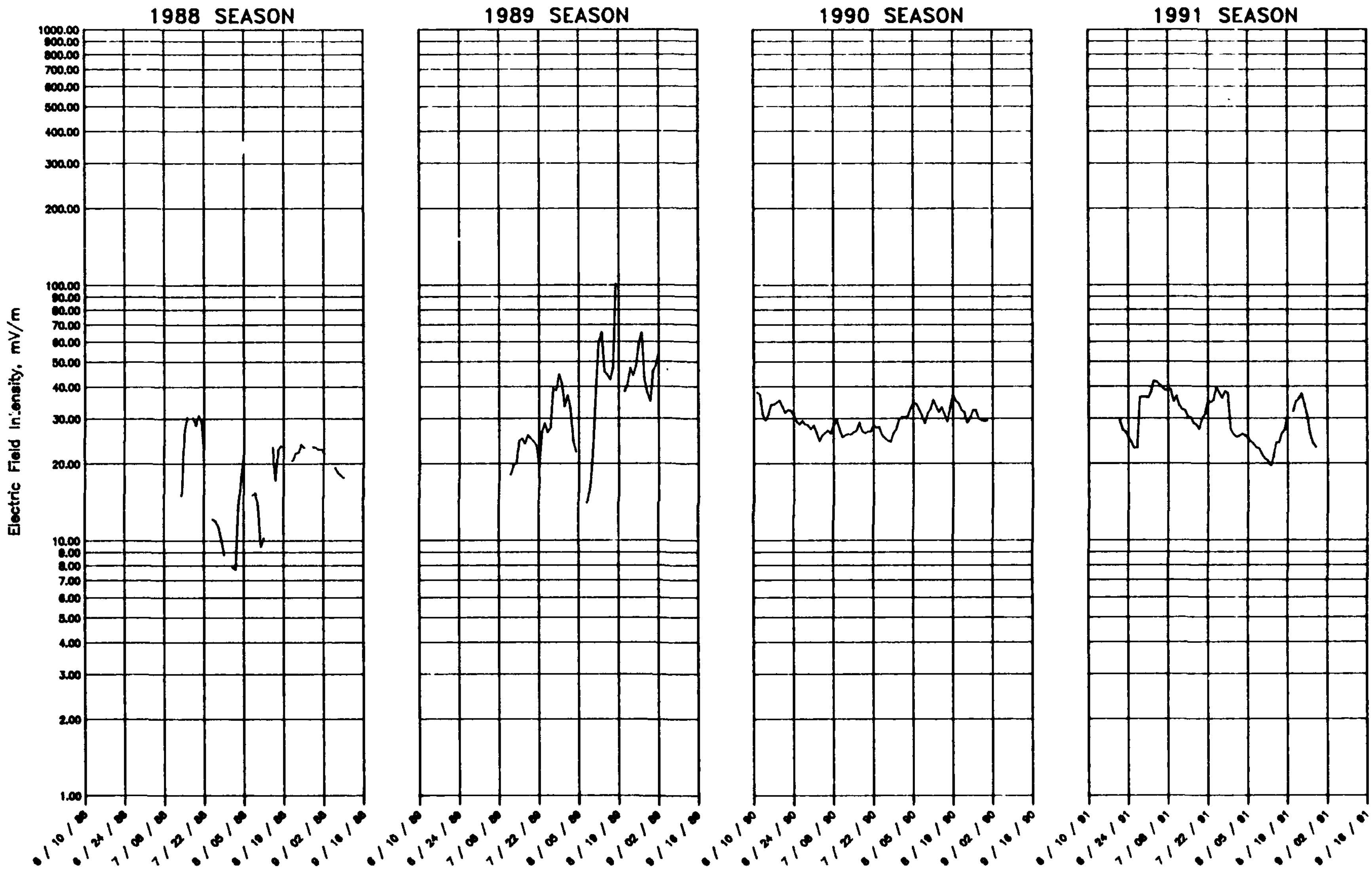


FIGURE F-15. DAILY AVERAGE ELECTRIC FIELD INTENSITIES FOR CHAMBER 5 AT THE SOIL AMOEBA GROUND STUDY SITE.

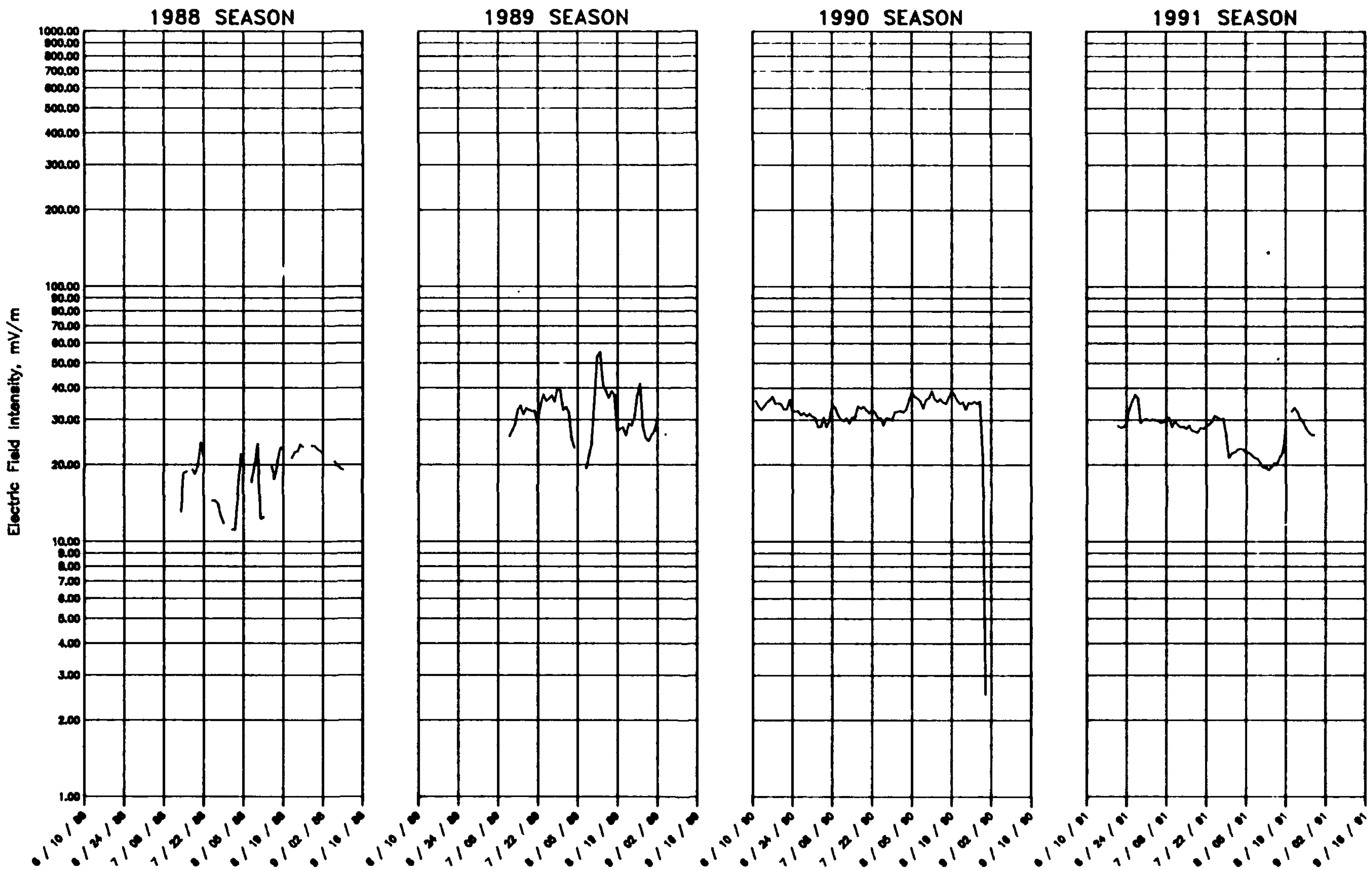


FIGURE F-16. DAILY AVERAGE ELECTRIC FIELD INTENSITIES FOR CHAMBER 6 AT THE SOIL AMOEBA GROUND STUDY SITE.

TABLE F-3. 60 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Soil Amoeba Studies

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991
6C2-1	<0.001	<	<	<	<	<	<	<[d]	<[d]
6T3-2	-	<	<	<	<	<	<	<0.001[c]	<[c]
6T3-3	-	-	-	<	<	<	<	<[c]	<[c]
6T4-1	-	<	<	<	<	<	<0.001	<[b]	<[c]
6T4-2	-	-	-	<	<	<0.001	<	<[b]	<[c]
6T4-3	-	-	-	<	<	<	<	<[b]	<[c]
6T4-4	-	-	-	<	<	<	<	<[b]	<[c]
6T4-5	-	-	-	<	<	<	<	<[b]	<[c]
6T4-6	-	-	-	<	<	<	<	<[b]	<[c]

a = antennas not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 A current.

\- = measurement point not established.
< = measurement est. <0.001 V/m based on earth E-field.

TABLE F-4. 60 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Soil Amoeba Studies

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991
6C2-1	0.32	0.61	0.194,0.28	0.058	0.256	0.98	1.19	0.22[d]	1.32[d]
6T3-2	0.087	0.130	0.134	0.078	0.130	0.41	#	0.193[c]	0.056[c]
6T3-3	-	-	-	0.085	0.125	0.35	#	0.186[c]	0.060[c]
6T4-1	-	0.48,0.52	0.40	0.072	0.32	0.18	0.35	0.070[b]	0.066[c]
6T4-2	-	-	-	0.046	0.162	0.145	0.30	0.048[b]	0.086[c]
6T4-3	-	-	-	0.065	0.082	0.24	0.34	0.068[b]	0.106[c]
6T4-4	-	-	-	0.037	0.24	0.27	0.23	0.057[b]	0.061[c]
6T4-5	-	-	-	0.053	0.182	0.18	0.33	0.049[b]	0.091[c]
6T4-6	-	-	-	0.098	0.084	0.33	0.34	0.069[b]	0.120[c]

a = antennas not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 A current.

- = measurement point not established.
= measurement precluded by antenna operation.

TABLE F-5. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Soil Amoeba Studies

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991
6C2-1	0.004	0.008	0.001,0.003	0.002	0.003	0.011	0.009	0.001[d]	0.014[d]
6T3-2	-	0.002	0.003	0.013	0.033	0.103	#	0.193[c]	0.008[c]
6T3-3	-	-	-	0.020	0.023	0.065	#	0.029[c]	0.013[c]
6T4-1	-	0.005,0.007	0.007	0.005	0.006	0.019	0.011	0.006[b]	0.005[c]
6T4-2	-	-	-	0.005	0.006	0.016	0.009	0.005[b]	0.005[c]
6T4-3	-	-	-	0.004	0.005	0.014	0.008	0.005[b]	0.004[c]
6T4-4	-	-	-	0.002	0.006	0.018	0.010	0.006[b]	0.005[c]
6T4-5	-	-	-	0.003	0.006	0.017	0.009	0.005[b]	0.004[c]
6T4-6	-	-	-	0.005	0.005	0.015	0.009	0.004[b]	0.004[c]

a = antennas not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 A current.
\- = measurement point not established.
\# = measurement precluded by antenna operation.

TABLE F-6. 76 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Soil Amoeba Studies

Site No., Meas. Pt.	1986 NS 4 A	1986 NEW 6 A	1986 SEW 6 A	1986 SEW 10 A, EX	1987 NS 15 A	1987 EW 15 A	1988 NS 75 A	1988 EW 75 A	1989 B 150 A	1990 B 150 A	1991 B 150 A
6C2-1	<	<	<	*	<	<	<	<	<	<	<
6T3-2	<	<	<	*	0.005	<	0.028	<	0.061	0.065	0.042
6T3-3	<	<	<	*	0.005	<	0.027	<	0.058	0.058	0.050
6T4-1	<	<	<	*	0.020	<	0.047	<	0.036	0.056	0.058
6T4-2	<	<	<	*	0.007	<	0.022	<0.001	0.030	0.030	0.033
6T4-3	<	<	<	*	0.004	<	0.030	<	0.045	0.041	0.048
6T4-4	<	<	<	*	0.014	<	0.035	<	0.028	0.044	0.037
6T4-5	<	<	<	*	0.007	<	0.036	<0.001	0.047	0.033	0.038
6T4-6	<	<	<	*	0.004	<	0.043	<	0.050	0.047	0.050

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.
A = amperes.

< = measurement est. <0.001 V/m based on earth E-field.
* = data cannot be extrapolated.

TABLE F-7. 76 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Soil Amoeba Studies

Site No., Meas. Pt.	1986				1987		1988		1989	1990	1991
	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	B 150 A
6C2-1	0.028	0.010	0.011	0.018	0.068	0.028	0.36	0.140	1.37	0.76	0.90
6T3-2	1.45	0.046	0.040	0.067	5.9	0.110	25	0.46	54	53	53
6T3-3	1.34	0.041	0.030	0.050	5.4	0.087	21	0.47	47	52	51
6T4-1	1.73	0.059	0.007	0.012	18.9	0.056	25	0.22	30	48	32
6T4-2	0.72	0.023	0.009	0.015	8.5	0.038	12.4	0.150	35	28	29
6T4-3	1.14	0.035	0.018	0.030	4.3	0.031	21	0.191	49	40	41
6T4-4	1.31	0.042	0.006	0.010	12.8	0.040	21	0.174	18.4	35	27
6T4-5	0.78	0.027	0.012	0.020	10.2	0.045	15.5	0.194	33	29	29
6T4-6	1.27	0.040	0.015	0.025	4.4	0.034	26	0.22	50	43	48

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.
A = amperes.

TABLE F-8. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Soil Amoeba Studies

Site No., Meas. Pt.	1986				1987		1988		1989	1990	1991
	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	B 150 A
6C2-1	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.002	0.001	0.004	0.004	0.002
6T3-2	0.28	0.009	0.001	0.002	1.03	0.004	4.9	0.011	10.1	10.1	9.6
6T3-3	0.170	0.006	0.001	0.002	0.64	0.003	3.1	0.007	6.3	6.2	5.9
6T4-1	0.100	0.003	0.001	0.002	0.35	0.001	1.82	0.007	4.1	3.7	3.4
6T4-2	0.082	0.003	0.001	0.002	0.29	0.001	1.50	0.006	3.3	3.1	2.9
6T4-3	0.071	0.002	<0.001	*	0.26	0.001	1.30	0.005	2.9	2.6	2.5
6T4-4	0.090	0.003	0.001	0.002	0.38	0.001	1.64	0.006	3.8	3.3	3.2
6T4-5	0.078	0.002	<0.001	*	0.27	<0.001	1.41	0.006	3.4	2.8	2.7
6T4-6	0.067	0.002	<0.001	*	0.24	0.001	1.22	0.005	2.7	2.4	2.4

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
EX = extrapolated data.
A = amperes.

* = data cannot be extrapolated.

APPENDIX G

BIRD SPECIES AND COMMUNITIES STUDIES

BIRD SPECIES AND COMMUNITIES STUDIES

The bird species and communities studies census migrating and resident bird populations using a line transect method. Bird populations in a given area are determined both as a whole and by individual species. The magnetic field is considered the most important electromagnetic (EM) factor influencing migrating birds; however, the electric fields in the air and the earth may also have an influence on population distributions.

IITRI field crews made ELF EM field measurements at 24 points within the five treatment and five control transects for the bird species and communities studies in Michigan in 1991. The study transects and the historical measurement points within those transects were unchanged from 1990. Measurement dates for 1991 and previous years appear in Table G-1.

TABLE G-1. EM FIELD MEASUREMENT DATES
Bird Species and Communities Studies, Michigan

Year	Measurement Dates	
1984	Aug 23, 24	
1985	May 6, 7	
1986	Sep 30	Oct 3, 6, 7, 13, 16
1987	Sep 23-25, 30	
1988	Sep 21, 23, 29, 30	Oct 4-6
1989	Sep 11, 14, 15, 18, 20, 22	
1990	Sep 25-28	Oct 3-5, 9, 11, 12
1991	Sep 24-27, 30	Oct 1-4, 15, 17

The positions of the 10 Michigan transects relative to the NRTF-Republic are shown on the composite map in Figure G-1. The transect numbers listed on the map are those used by IITRI. Table G-2 provides a cross-reference of IITRI transect numbers, investigator transect names, and township, range, and section numbers for the transects.

EM field measurements for Michigan for 1991 and previous years are found in Tables G-3 through G-8. Tables G-3, G-4, and G-5 present 60 Hz data for the air electric field, earth electric field, and magnetic flux density, respectively. Tables G-6, G-7, and G-8 present 76 Hz data for these fields as well as the corresponding operating currents of the NRTF-Republic.

TABLE G-2. TRANSECT NO. CROSS-REFERENCE
Bird Species and Communities Studies

IITRI Transect No.	Investigator's Transect Name	Location		
		Township	Range	Section(s)
10C1	Carney Lake	T41N	R29W	33, 34, 35, 36
10C2	Skunk Creek	T42N	R27W	19, 30
		T42N	R28W	14, 23, 24
10C5	Arnold	T43N	R25W	31, 32, 33, 34
10C12	Lost Lake	T41N	R29W	21, 26, 27, 28, 35
10C13	Bob's Creek	T44N	R26W	13, 23, 24, 26
10T1	Leeman's Road	T43N	R29W	14, 23, 26, 35
10T2	Turner Road	T43N	R29W	1, 12
		T44N	R29W	36
10T3	Flat Rock Creek	T45N	R28W	19, 30, 31
10T4	Schwartz Creek	T45N	R28W	31
		T45N	R29W	26, 27, 35, 36
10T11	Heart Lake	T45N	R28W	7, 18, 19
		T45N	R29W	1, 12

Considerable year-to-year variability in the 60 Hz EM fields is evident. The primary factors in this variability at treatment sites are changes in power line loading conditions (which are unknown) and differences in the configuration of the antennas at the time of measurement. Notes on the antenna configurations are included in the tables primarily for engineering use. The 60 Hz measurements at treatment transects in 1986-1991 (excluding 1989) were taken while the antennas were off, and are representative of 60 Hz levels present during maintenance periods. In 1989, 60 Hz measurements were taken during full-power operation of the antennas with an unmodulated signal. These values indicate that 60 Hz EM fields present during operation of the antennas are comparable to those present when the antennas are off. It was not possible to take 60 Hz measurements at some points on treatment transects in 1989 and 1990 because of antenna operation with a modulated signal. These cases are noted in the data tables.

Annual variations in the 60 Hz EM fields measured at the control transects are also caused by differences in power line loading, but are not dependent on the antennas or their configuration because of the distance of these transects from the antenna. The 60 Hz EM field values at the control transects, nonetheless, are about as variable as those at thc treatment transects.

Overall, the 60 Hz EM fields measured at all transects in 1990 are consistent with previous field values and with the expected differences in power line loads and the antenna configuration. Regardless of the field variability associated with the measurement condition, 76 Hz EM fields at the treatment transects

consistently dominate the 60 Hz EM fields at the treatment and control transects, and the ratios of 60 Hz EM fields between matched treatment/control transects continue to meet the exposure criteria guidelines established at the beginning of the study.

The 76 Hz EM field measurements in 1991 were made with 150 ampere antenna currents, the predominant operating current of the NRTF-Republic since 4 May 1989. The antenna currents at which measurements were made in each year are given in the column headings of Tables G-6 through G-8. The annual increases in field magnitudes reflect the level of antenna current at the time of measurement: 4 or 6 amperes in 1986, 15 amperes in 1987, 75 amperes in 1988, and 150 amperes in 1989, 1990, and 1991. The 1991 measurements are consistent with the 1989 and 1990 measurements at the same current, and are proportional to the 1986, 1987, and 1988 measurements made at lower currents.

No measurements were conducted along these study transects during the periods when the EW antenna was down for repairs. However, engineering estimates of the EM exposures at the treatment transects under this antenna condition have been made on the basis of measurements taken at other ecological study sites. The Schwartz Creek transect (10T4), which parallels the southern EW antenna, was the most affected. Measurements at the upland flora and soil microflora study site situated along this same antenna element indicate that EM exposure at all locations along 10T4 were reduced to about one-third those with both antennas on at full current. The relatively high exposures along the de-energized EW antenna are caused by significant cross-coupling from the operating NS antenna.

Based on 1988 measurements during individual operation of the two antennas, EM exposures at the other four treatment transects which parallel the NS element should have been only marginally affected. Any changes in field intensities would be expected to be on the order of 10 percent or less. The one exception to this would be where the Flat Rock Creek transect crosses the southern EW antenna element at measurement point 10T3-3. Because this point is closer to the EW than the NS right-of-way, field intensities here are normally dominated by the EW element and thus are considerably higher than at other locations on the transect. With the EW antenna off, the exposures in the vicinity of 10T3-3 would have fallen to levels similar to those at 10T3-1 and -2.

EM field reductions are also expected to have occurred along control transects during periods when the EW antenna was off. Such reductions would have been unique to each transect because of differences in their relative positions to the antenna elements. Nonetheless, any reduction in the 76 Hz EM fields along control transects, where low intensities are desired, should not be of great concern as this situation actually improves the 76 Hz EM field ratios between treatment and control transects.

Measured values of the electric and magnetic fields taken along transects 10T1, 10T2, 10T3, 10T4, and 10T11 in 1990 are included in this report in Table G-9. Measurements were taken at the start and finish of each transect and at the "X" flags between transect sub-segments. Table G-9 also includes data from applicable historical measurement locations. Graphs of the EM field intensities along these transects are presented in Figures G-2 and G-3. A more thorough discussion of these special measurements and results appears in a previous report.[11]

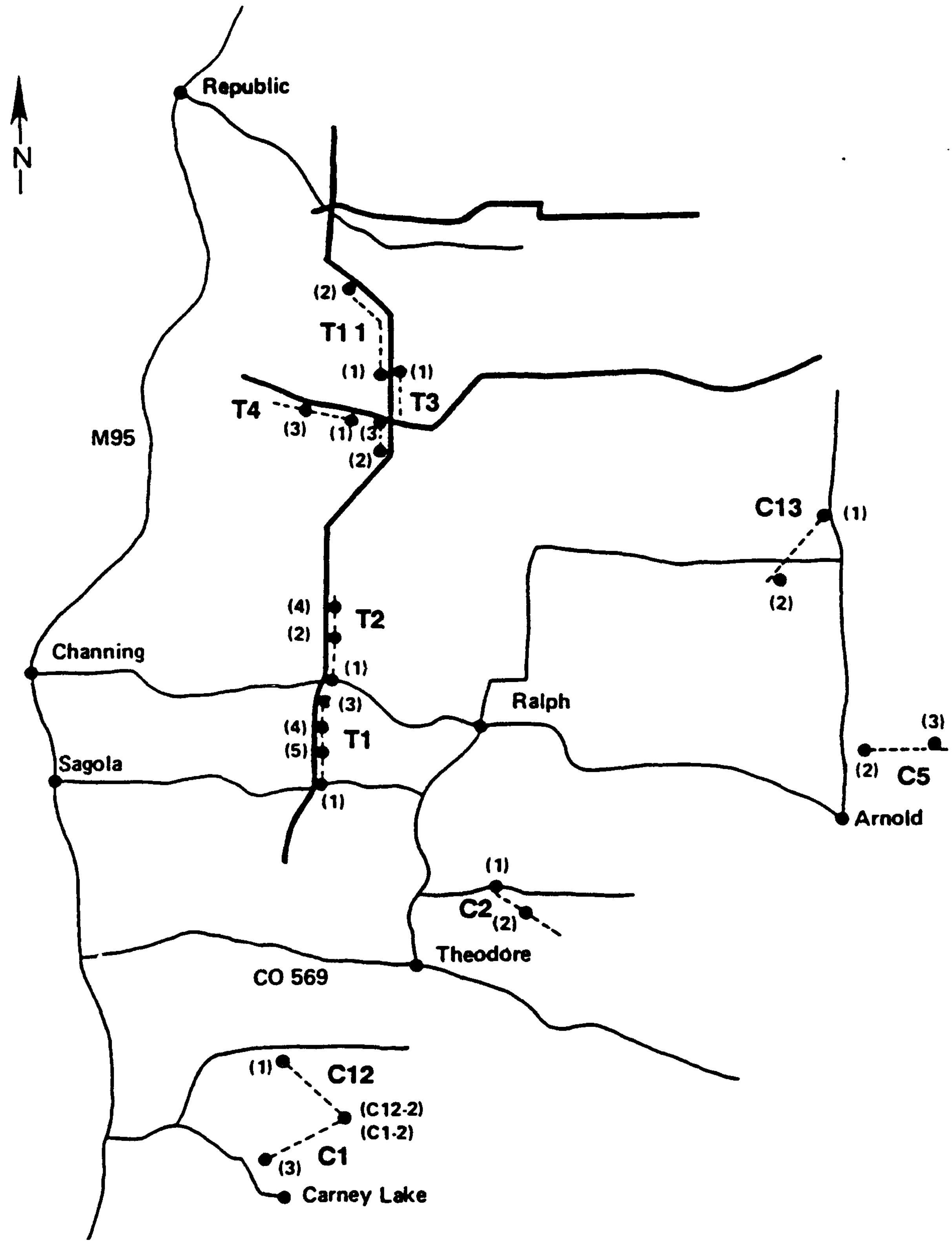


FIGURE G-1. POSITIONS OF BIRD SPECIES AND COMMUNITIES STUDY TRANSECTS RELATIVE TO NRTF-REPUBLIC ANTENNA ELEMENTS.

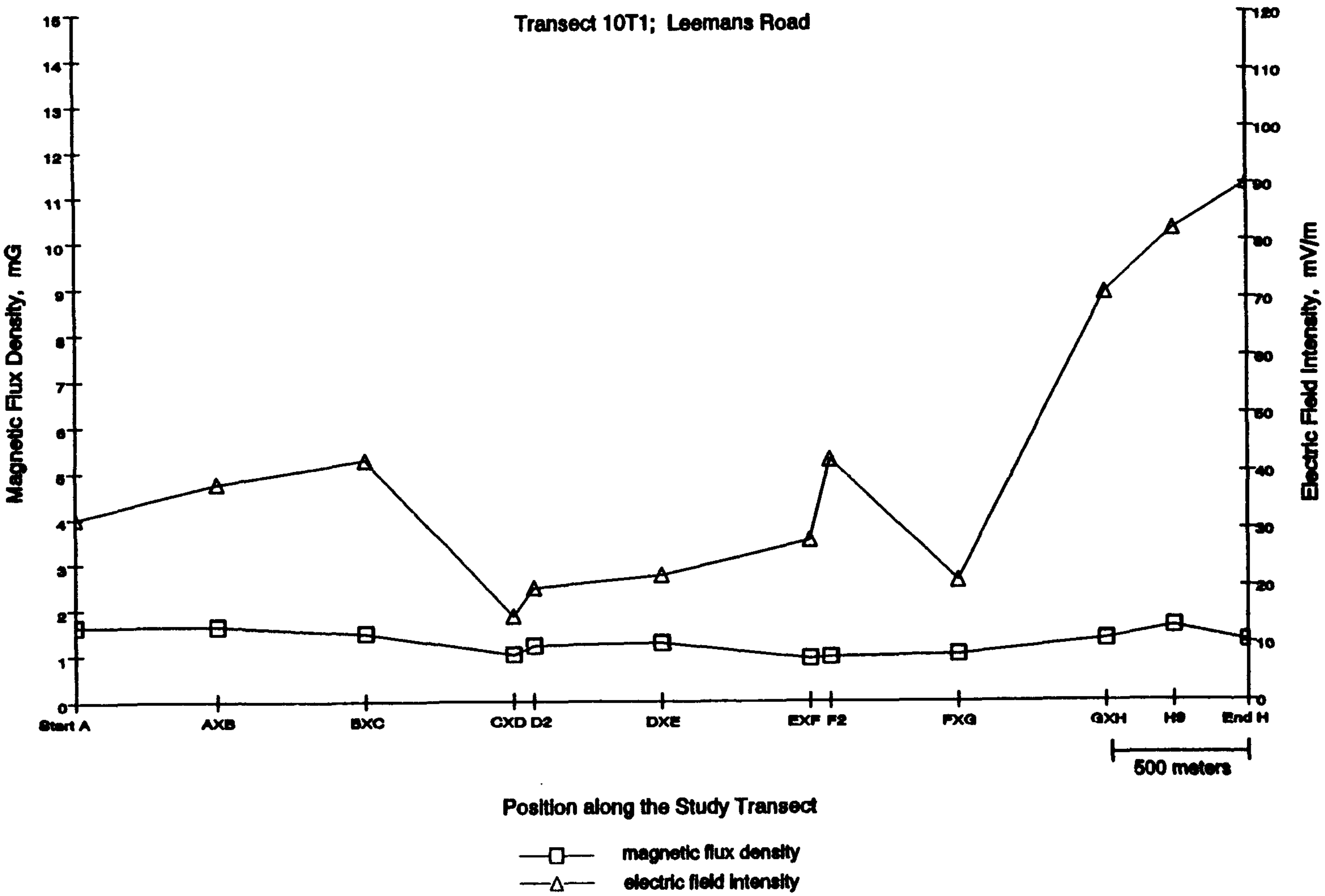


FIGURE G-2. EM FIELD VARIATIONS ALONG STUDY TRANSECT 10T1.

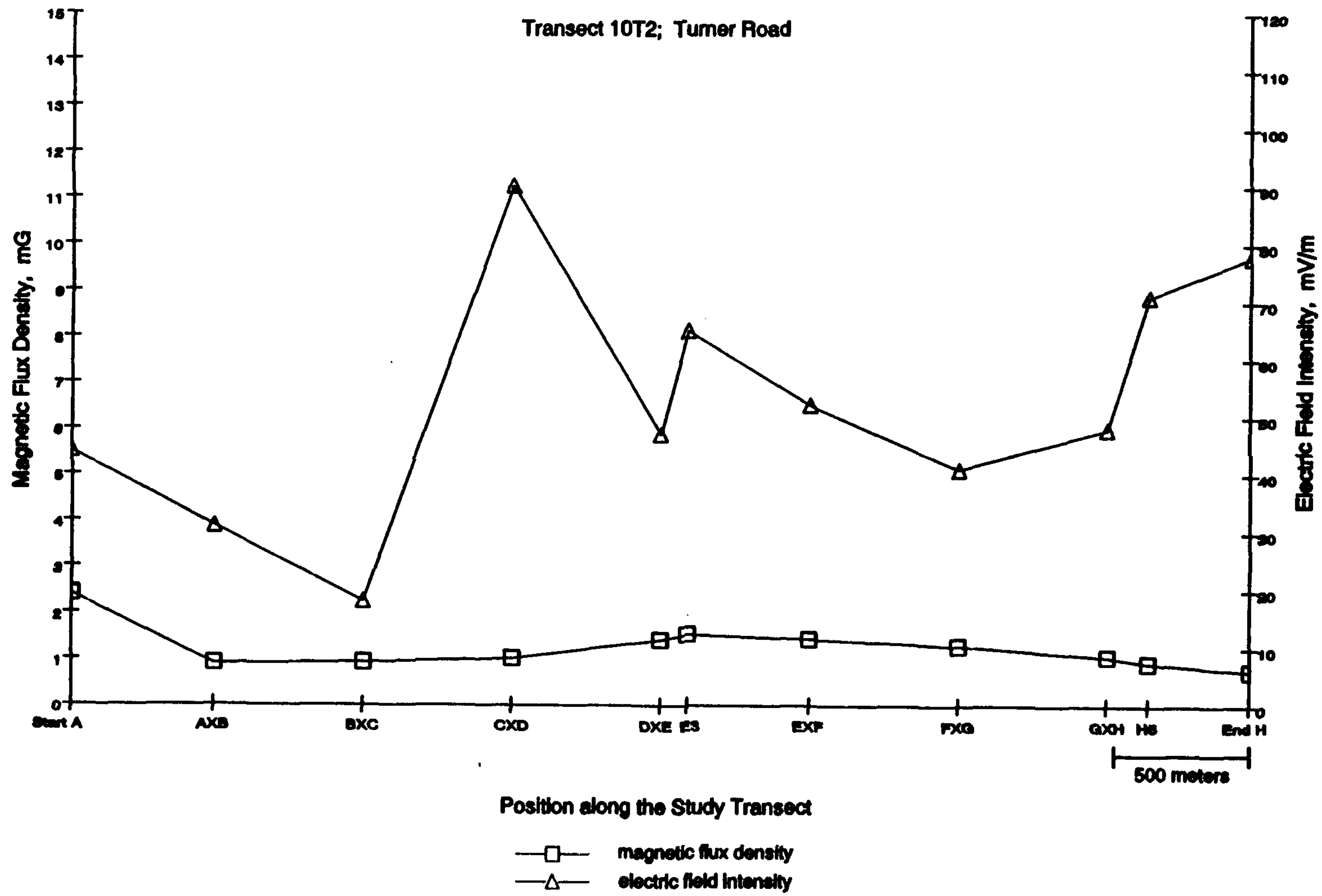


FIGURE G-3. EM FIELD VARIATIONS ALONG STUDY TRANSECT 10T2.

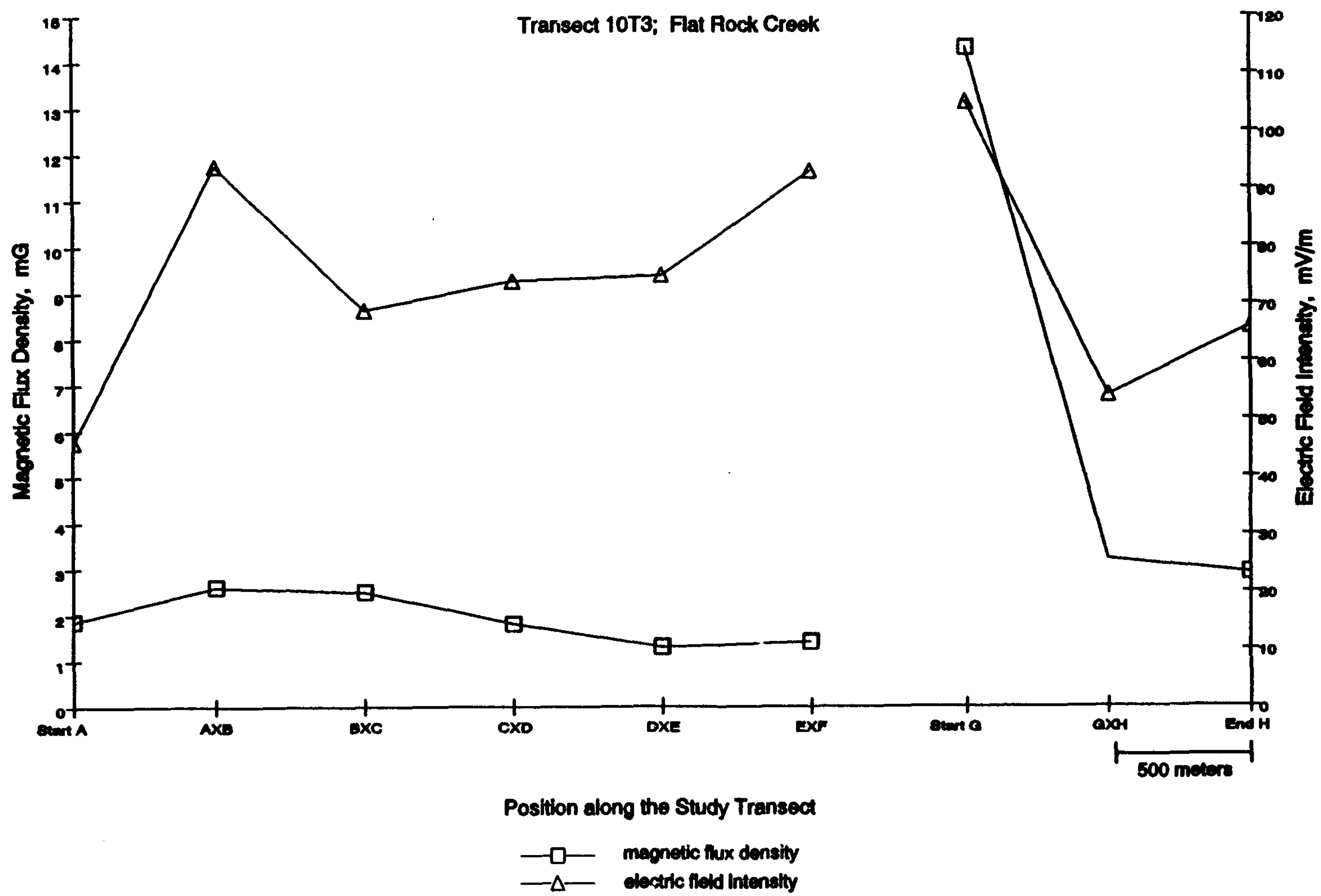


FIGURE G-4. EM FIELD VARIATIONS ALONG STUDY TRANSECT 10T3.

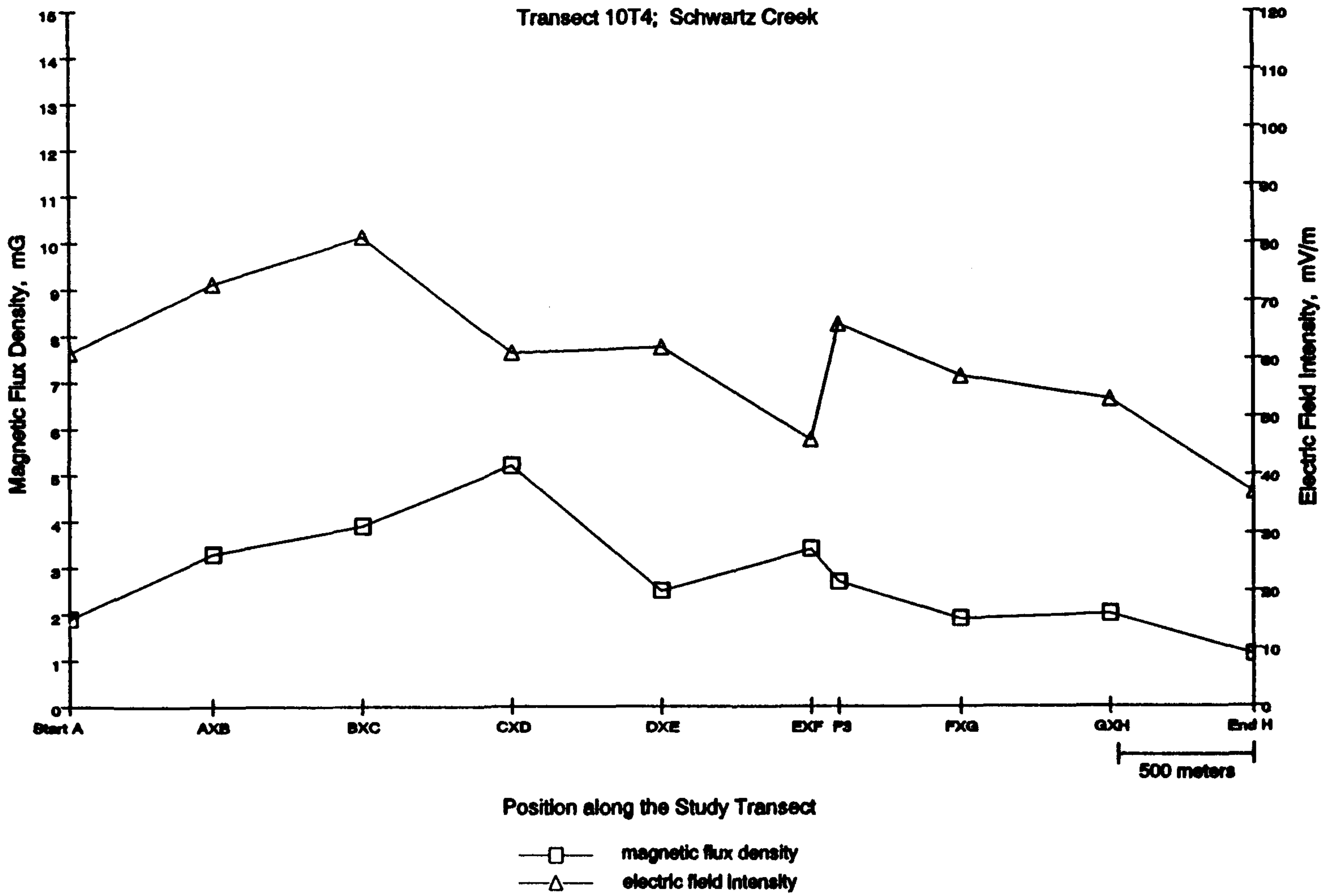


FIGURE G-5. EM FIELD VARIATIONS ALONG STUDY TRANSECT 10T4.

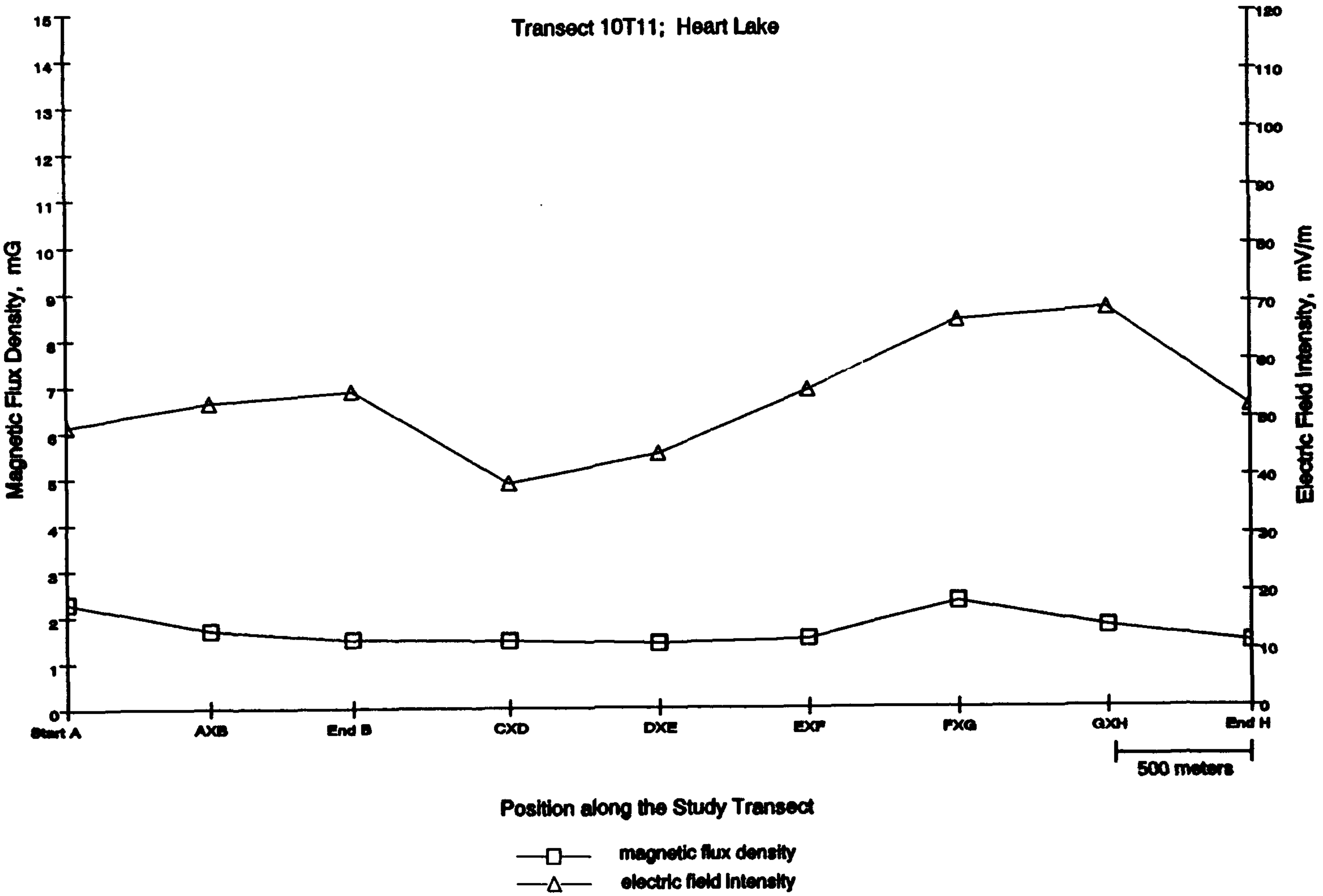


FIGURE G-6. EM FIELD VARIATIONS ALONG STUDY TRANSECT 10T11.

TABLE G-3. 60 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Bird Species and Communities Studies
Michigan Transects

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991
10C1-2	-	<	<	<	<	<	<	<[d]	<[d]
10C1-3	-	-	<	<	<	<	<	<[d]	<[d]
10C2-1	-	<	<	<	<	<	<	<[d]	<[d]
10C2-2	-	<	<	<	<	<	<	<[d]	<[d]
10C5-2	-	<	<	<	<	<	<	<[d]	<[d]
10C5-3	-	<	<	<	<	<	<	<[d]	<[d]
10C12-1	-	-	<	<	<	<	<	<[d]	<[d]
10C12-2	-	-	<	<	<	<	<	<[d]	<[d]
10C13-1	-	-	<	<	<	<	<	<[d]	<[d]
10C13-2	-	-	<	<	<	<	<	<[d]	<[d]
10T1-1	-	<	<	<	<	<	<0.001	<[b]	<[c]
10T1-3	-	-	<	<	<	<	<	<[b]	<[b]
10T1-4	-	-	-	<	<	<	<	<[b]	<[c]
10T1-5	-	-	-	<	<	<	<0.001	<[b]	<[c]
10T2-1	-	<0.001	<	<	<	<	<	<[c]	<[b]
10T2-2	-	-	-	<	<	<	<	<[b]	<[b]
10T2-4	-	-	<	<	<	0.008	#	<[b]	<[b]
10T3-1	-	<	<	<	<	<	<	#	<[b]
10T3-2	-	<	<	<	<	<	<	#	<[c]
10T3-3	-	-	-	<	<	<0.001	<0.001	#	<[c]
10T4-1	-	<	<	<	<	<	<	#	<[c]
10T4-3	-	-	-	<	<	<	<	#	<[c]
10T11-1	-	-	<	<	<	<0.001	<0.001	#	<[b]
10T11-2	-	-	<	<	0.011	<0.001	<0.001	#	<[b]

a = antennas not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 A current.

\- = measurement point not established.
\# = measurement precluded by antenna operation.
< = measurement est. <0.001 V/m based on earth E-field.

TABLE G-4. 60 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Bird Species and Communities Studies
Michigan Transects

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991
10C1-2	-	0.62	0.106,0.141	0.101	0.059	0.20	0.073	0.27[d]	0.105[d]
10C1-3	-	-	0.26,0.27	0.055	0.21	0.32	0.72	0.079[d]	0.78[d]
10C2-1	-	0.98	0.138	0.041	0.038	0.087	0.080	0.076[d]	0.076[d]
10C2-2	-	0.35	0.21	0.055	0.048	0.047	0.069	0.076[d]	0.057[d]
10C5-2	-	0.35	0.45	0.193	0.116	0.23	0.053	0.050[d]	0.037[d]
10C5-3	-	0.111	0.23	0.25	0.103	0.126	0.050	0.073[d]	0.160[d]
10C12-1	-	-	0.194,0.28	0.058	0.256	0.98	1.19	0.22[d]	1.32[d]
10C12-2	-	-	0.106,0.141	0.101	0.059	0.20	0.073	0.27[d]	0.105[d]
10C13-1	-	-	0.34,0.52	0.30	0.40	0.37	0.78	0.099[d]	0.156[d]
10C13-2	-	-	0.143,0.31	0.139	0.157	0.121	0.039	0.074[d]	0.212[d]
10T1-1	-	0.076	0.061	0.034	0.099	0.21	0.077	0.039[b]	0.038[c]
10T1-3	-	-	0.38	0.120	0.20	0.51	#	0.106[b]	0.092[b]
10T1-4	-	-	-	0.111	0.085	0.30	0.076	0.029[b]	0.040[c]
10T1-5	-	-	-	0.040	0.052	0.116	0.052	0.021[b]	0.023[c]
10T2-1	-	0.42	0.194	0.050	0.058	0.23	0.034	0.130[c]	0.123[b]
10T2-2	-	-	-	0.058	0.052	0.24	0.023	0.028[b]	0.090[b]
10T2-4	-	-	0.158	0.054	0.029	0.166	0.164	0.013[b]	0.093[b]
10T3-1	-	0.30	0.23	0.145	0.164	0.070	#	#	0.148[b]
10T3-2	-	0.26	0.117	0.069	0.103	0.075	#	#	0.173[c]
10T3-3	-	-	-	0.094	0.120	0.132	0.32	#	0.39[c]
10T4-1	-	0.29	0.132	0.129	0.093	0.087	#	#	0.20[c]
10T4-3	-	-	-	0.112	0.22	0.166	0.087	#	0.21[c]
10T11-1	-	-	0.23	0.172	0.106	0.095	0.25	#	0.145[b]
10T11-2	-	-	0.26,0.50	0.58	0.45	0.196	0.21	#	0.34[b]

a = antennas not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 A current.

\- = measurement point not established.
\# = measurement precluded by antenna operation.

TABLE G-5. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Bird Species and Communities Studies
Michigan Transects

Site No., Meas. Pt.	1983[a]	1984[a]	1985[a]	1986[b]	1987[c]	1988[c]	1989[d]	1990	1991
10C1-2	-	0.001	0.001	<0.001	<0.001	0.001	0.001	0.001[d]	0.001[d]
10C1-3	-	-	0.001,0.003	<0.001	0.003	0.002	0.007	0.002[d]	0.010[d]
10C2-1	-	0.005	0.004	<0.001	<0.001	<0.001	0.001	0.001[d]	0.001[d]
10C2-2	-	0.003	0.003	<0.001	0.001	0.001	0.001	0.001[d]	0.001[d]
10C5-2	-	0.008	0.009	0.006	0.005	0.006	0.002	0.001[d]	0.008[d]
10C5-3	-	0.001	0.002	0.002	0.001	0.001	0.001	0.001[d]	0.002[d]
10C12-1	-	-	0.001,0.003	0.002	0.003	0.011	0.009	0.001[d]	0.014[d]
10C12-2	-	-	0.001	<0.001	<0.001	0.001	0.001	0.001[d]	0.001[d]
10C13-1	-	-	0.007,0.010	0.007	0.005	0.003	0.009	0.003[d]	0.011[d]
10C13-2	-	-	0.001,<0.001	0.001	0.001	0.001	0.001	0.001[d]	0.001[d]
10T1-1	-	0.006	0.004	0.002	0.005	0.016	0.005	0.002[b]	0.002[c]
10T1-3	-	-	0.002	0.003	0.005	0.017	#	0.003[b]	0.005[b]
10T1-4	-	-	-	0.003	0.003	0.009	0.002	0.001[b]	0.002[c]
10T1-5	-	-	-	0.003	0.016	0.012	0.003	0.001[b]	0.002[c]
10T2-1	-	0.002	0.002	0.003	0.005	0.012	0.001	0.007[c]	0.009[b]
10T2-2	-	-	-	<0.001	0.002	0.008	0.001	0.001[b]	0.006[b]
10T2-4	-	-	0.001	0.002	0.001	0.004	0.001	<0.001[b]	0.004[b]
10T3-1	-	0.001	0.001	0.006	0.003	0.004	#	#	0.003[b]
10T3-2	-	0.001	<0.001	0.008	0.005	0.004	#	#	0.012[c]
10T3-3	-	-	-	0.012	0.007	0.017	0.010	#	0.030[c]
10T4-1	-	0.001	<0.001	0.002	0.002	0.003	#	#	0.004[c]
10T4-3	-	-	-	0.001	0.003	0.004	0.002	#	0.006[c]
10T11-1	-	-	<0.001	0.006	0.006	0.003	0.003	#	0.003[b]
10T11-2	-	-	0.001,<0.001	0.008	0.005	0.004	<0.001	#	0.006[b]

a = antennas not constructed.
b = antennas off, grounded at transmitter.
c = antennas off, connected to transmitter.
d = antennas on, 150 A current.

- = measurement point not established.
= measurement precluded by antenna operation.

TABLE G-6. 76 Hz AIR ELECTRIC FIELD INTENSITIES (V/m)
Bird Species and Communities Studies
Michigan Transects

Site No., Meas. Pt.	1986				1987		1988		1989	1990	1991
	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	B 150 A
10C1-2	<	<	<	*	<	<	<	<	<	<	<
10C1-3	<	<	<	*	<	<	<	<	<	<	<
10C2-1	<	<	<	*	<	<	<	<	<	<	<
10C2-2	<	<	<	*	<	<	<	<	<	<	<
10C5-2	<	<	<	*	<	<	<	<	<	<	<
10C5-3	<	<	<	*	<	<	<	<	<	<	<
10C12-1	<	<	<	*	<	<	<	<	<	<	<
10C12-2	<	<	<	*	<	<	<	<	<	<	<
10C13-1	<	<	<	*	<	<	<	<	<	<	<
10C13-2	<	<	<	*	<	<	<	<	<	<	<
10T1-1	<	<	<	*	0.005	<	0.022	<	0.036	0.036	0.037
10T1-3	0.002	<	<	*	0.007	<	0.038	<0.001	0.068	0.081	0.084
10T1-4	<	<	<	*	0.004	<	0.024	<	0.036	0.040	0.033
10T1-5	<	<	<	*	0.003	<	0.010	<	0.022	0.020	0.022
10T2-1	0.002	<	<	*	0.006	<	0.033	<0.001	0.059	0.088	0.072
10T2-2	0.002	<	<	*	0.007	<	0.047	0.003	0.062	0.062	0.069
10T2-4	0.002	<	<	*	0.007	<	0.028	0.007	0.062	0.060	0.075
10T3-1	0.004	<	<	*	0.005	0.003	0.016	0.019	0.040	0.050	0.050
10T3-2	0.004	<	0.001	0.002	0.006	0.003	0.048	0.034	0.071	0.070	0.067
10T3-3	0.005	<	0.017	0.028	0.005	0.009	0.046	0.120	0.170	0.130	0.125
10T4-1	0.002	<	0.003	0.005	0.003	0.006	0.042	0.038	0.049	0.051	0.067
10T4-3	<	<	0.003	0.005	0.001	0.008	0.018	0.054	0.078	0.062	0.072
10T11-1	<	<	<	*	0.004	0.002	0.019	0.014	0.051	0.053	0.064
10T11-2	<	<	<	*	0.038	0.009	0.059	0.017	0.108	0.27	0.185

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
A = amperes.

EX = extrapolated data.
* = data cannot be extrapolated.
< = measurement est. <0.001 V/m based on earth E-field.

TABLE G-7. 76 Hz EARTH ELECTRIC FIELD INTENSITIES (mV/m)
Bird Species and Communities Studies
Michigan Transects

Site No., Meas. Pt.	1986				1987		1988		1989	1990	1991
	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	B 150 A
10C1-2	0.004	0.003	0.004	0.007	0.015	0.012	0.074	0.058	0.153	0.31	0.139
10C1-3	0.013	0.004	0.002	0.003	0.049	0.011	0.26	0.060	0.41	0.44	0.50
10C2-1	0.017	0.002	0.007	0.012	0.073	0.021	0.30	0.095	0.78	0.70	0.64
10C2-2	0.011	0.003	0.007	0.012	0.037	0.020	0.176	0.100	0.33	0.43	0.30
10C5-2	0.001	0.003	0.007	0.012	0.014	0.023	0.073	0.119	0.26	0.28	0.21
10C5-3	0.005	0.003	0.009	0.015	0.017	0.027	0.091	0.143	0.30	0.28	0.24
10C12-1	0.028	0.010	0.011	0.018	0.068	0.028	0.36	0.140	1.37	0.76	0.90
10C12-2	0.004	0.003	0.004	0.007	0.015	0.012	0.074	0.058	0.153	0.31	0.139
10C13-1	0.024	0.027	0.104	0.173	0.057	0.24	0.32	1.39	4.8	4.2	3.3
10C13-2	0.024	0.023	0.098	0.163	0.089	0.29	0.34	1.07	2.1	2.7	2.4
10T1-1	0.85	0.028	0.008	0.013	2.8	0.015	13.0	0.115	42	32	41
10T1-3	2.2	0.068	0.077	0.128	7.1	0.147	33	0.86	74	82	77
10T1-4	0.96	0.030	0.031	0.052	4.1	0.087	19.8	0.46	35	42	40
10T1-5	0.65	0.020	0.006	0.010	2.3	0.015	10.9	0.098	20	19.7	19.0
10T2-1	1.42	0.043	0.077	0.128	5.3	0.25	31	1.05	48	44	76
10T2-2	1.69	0.056	0.107	0.178	7.0	0.34	33	1.77	53	65	67
10T2-4	0.59	0.056	0.158	0.26	5.0	0.49	26	2.6	79	71	57
10T3-1	0.82	0.23	0.60	1.00	4.9	2.1	26	10.1	47	46	47
10T3-2	1.24	0.133	1.05	1.75	5.4	2.7	21	31	61	66	76
10T3-3	1.36	(0.35)	3.6	6.0	4.8	7.5	43	54	111	105	105
10T4-1	0.88	0.137	1.58	2.6	2.4	4.8	14.5	19.3	62	61	58
10T4-3	0.46	0.139	1.92	3.2	1.30	8.1	5.4	39	68	66	67
10T11-1	0.67	0.27	0.59	0.98	3.9	1.97	17.6	8.9	47	49	47
10T11-2	1.38	0.93	0.44	0.73	7.3	2.9	32	12.6	105	86	72

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
A = amperes.
EX = extrapolated data.

TABLE G-8. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Bird Species and Communities Studies
Michigan Transects

Site No., Meas. Pt.	1986				1987		1988		1989	1990	1991
	NS 4 A	NEW 6 A	SEW 6 A	SEW 10 A, EX	NS 15 A	EW 15 A	NS 75 A	EW 75 A	B 150 A	B 150 A	B 150 A
10C1-2	<0.001	<0.001	<0.001	*	<0.001	<0.001	<0.001	<0.001	0.001	0.001	0.001
10C1-3	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.002	<0.001	0.003	0.003	0.001
10C2-1	<0.001	<0.001	<0.001	*	0.001	0.001	0.005	0.002	0.009	0.009	0.007
10C2-2	<0.001	<0.001	<0.001	*	0.001	<0.001	0.003	0.002	0.005	0.005	0.005
10C5-2	<0.001	<0.001	<0.001	*	<0.001	0.001	0.001	0.002	0.005	0.005	0.005
10C5-3	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.001	0.001	0.003	0.003	0.003
10C12-1	<0.001	<0.001	<0.001	*	<0.001	<0.001	0.002	0.001	0.004	0.004	0.002
10C12-2	<0.001	<0.001	<0.001	*	<0.001	<0.001	<0.001	<0.001	0.001	0.001	0.001
10C13-1	<0.001	<0.001	<0.001	*	0.001	0.002	0.002	0.009	0.066	0.066	0.047
10C13-2	<0.001	<0.001	<0.001	*	<0.001	0.001	0.002	0.006	0.015	0.015	0.014
10T1-1	0.044	0.001	<0.001	*	0.179	0.001	0.84	0.005	1.87	1.63	1.60
10T1-3	0.047	0.001	0.007	0.012	0.176	0.001	0.84	0.010	1.70	1.62	1.64
10T1-4	0.026	0.001	0.001	0.002	0.103	0.002	0.49	0.014	1.02	0.95	0.91
10T1-5	0.034	0.001	0.001	0.002	0.49	0.002	0.61	0.008	1.31	1.20	1.19
10T2-1	0.066	0.002	0.001	0.002	0.25	0.001	1.21	0.010	2.5	2.4	2.3
10T2-2	0.043	0.001	0.001	0.002	0.165	0.002	0.80	0.010	1.61	1.54	1.55
10T2-4	0.026	0.001	0.001	0.002	0.097	0.002	0.46	0.005	0.97	0.92	0.91
10T3-1	0.029	0.003	0.007	0.012	0.188	0.015	0.96	0.078	1.89	1.87	1.85
10T3-2	0.081	0.002	0.013	0.022	0.29	0.031	1.61	0.161	2.9	2.9	2.8
10T3-3	0.116	(0.040)	0.58	0.97	0.196	0.89	1.11	7.7	15.0	14.3	14.0
10T4-1	0.025	0.001	0.081	0.135	0.038	0.191	0.20	1.00	1.92	1.89	1.90
10T4-3	0.025	0.001	0.119	0.198	0.011	0.32	0.051	1.42	2.9	2.7	2.6
10T11-1	0.033	0.002	0.006	0.010	0.24	0.015	1.09	0.072	2.3	2.3	2.0
10T11-2	0.042	0.003	0.003	0.005	0.31	0.006	1.42	0.033	2.9	2.8	2.8

NS = north-south antenna.
EW = east-west antenna.
NEW = northern EW antenna element.
SEW = southern EW antenna element.
B = NS + EW antennas, standard phasing.
A = amperes.
EX = extrapolated data.
* = data cannot be extrapolated.

TABLE G-9. 1990 EM FIELD VARIATIONS ALONG MICHIGAN TRANSECTS BIRD SPECIES AND COMMUNITIES STUDIES

Study Transect	Sub-Transect Location	Magnetic Flux Density (mG)	Electric Field Intensity (mV/m)
10T1-1	Start A	1.63	32
10T1	AXB	1.64	38
:0T1	BXC	1.48	42
10T1	CXD	1.02	14.8
10T1-5	D2	1.20	19.7
10T1	DXE	1.26	22
10T1	EXF	0.93	28
10T1-4	F2	0.95	42
10T1	FXG	1.01	21
10T1	GXH	1.34	71
10T1-3	H9	1.62	82
10T1	End H	1.30	90
10T2-1	Start A	2.4	44
10T2	AXB	0.89	31
10T2	BXC	0.92	18
10T2	CXD	1.01	90
10T2	DXE	1.42	47
10T2-2	E3	1.54	65
10T2	EXF	1.43	52
10T2	FXG	1.30	41
10T2	GXH	1.06	48
10T2-4	H5	0.92	71
10T2	End H	0.75	78
10T3-1	Start A	1.87	46
10T3	AXB	2.6	94
10T3	BXC	2.5	69
10T3	CXD	1.80	74
10T3	DXE	1.30	75
10T3	EXF	1.40	93
10T3-3	Start G	14.3	105
10T3	GXH	3.2	54
10T3-2	End H	2.9	66
10T4-1	Start A	1.89	61
10T4	AXB	3.3	73
10T4	BXC	3.9	81
10T4	CXD	5.2	61
10T4	DXE	2.5	62
10T4	EXF	3.4	46
10T4-3	F3	2.7	66
10T4	FXG	1.90	57
10T4	GXH	2.0	53
10T4	End H	1.13	37
10T11-1	Start A	2.3	49
10T11	AXB	1.70	53
10T11	End B	1.50	55
10T11	CXD	1.46	39
10T11	DXE	1.40	44
10T11	EXF	1.50	55
10T11	FXG	2.3	67
10T11	GXH	1.74	69
10T11	End H	1.40	52

Notes: Measurements taken at "X" flag between sub-transects except as noted.
Antenna conditions: 150 amperes, 76 Hz.

APPENDIX H

ELECTROMAGNETIC EXPOSURE CRITERIA

ELECTROMAGNETIC EXPOSURE CRITERIA

Because the electromagnetic (EM) field intensities and/or exposure durations required to produce a bioeffect are not known, EM exposure criteria were established to assist investigators in selecting study sites. These exposure criteria ensure that the 76 Hz EM fields at a treatment site are significantly larger than the 76 Hz EM fields at its paired control site, and also significantly larger than the 60 Hz EM fields at both sites. In addition, the exposure criteria verify that there is not a substantial difference in the ambient 60 Hz EM field intensities between the treatment and control sites.

The EM exposure criteria used in site selection are expressed in equation form as follows:

$$T_{(76\ Hz)}/C_{(76\ Hz)} > 10 \qquad (1)$$

$$T_{(76\ Hz)}/T_{(60\ Hz)} > 10 \qquad (2)$$

$$T_{(76\ Hz)}/C_{(60\ Hz)} > 10 \qquad (3)$$

$$0.1 < T_{(60\ Hz)}/C_{(60\ Hz)} < 10 \qquad (4)$$

where $T_{(76\ Hz)}$ = treatment site exposure due to ELF Communications System
$T_{(60\ Hz)}$ = treatment site exposure due to power lines
$C_{(76\ Hz)}$ = control site exposure due to ELF Communications System
$C_{(60\ Hz)}$ = control site exposure due to power lines

Based on the exposure assessment, each possible treatment and control site pairing was classified as acceptable, conditionally acceptable, or unacceptable. These categories are defined as follows:

Acceptable. A treatment/control site pair was placed in this category if it satisfied all four EM exposure inequalities for each of the EM fields applicable to the study. For example, the small mammals and nesting birds studies would be concerned with both the soil and air electric fields as well as the magnetic fields. The soil arthropods and earthworms studies, however, would not be concerned with the electric field in the air, since this field terminates at the earth's surface and would not be expected to impact biota existing in the soil or litter layer.

Conditionally Acceptable. A treatment/control site pair was placed in this category if it approached, but did not meet, the criteria for acceptability. This category was established because the EM exposure criteria were not rigidly defined. The assumption was made that a difference of one order of magnitude or more would constitute a significant difference

between treatment and control sites for these studies, but without knowing what effects will be experienced, if any. It is difficult to define this difference *a priori*. Furthermore, the EM field measurements themselves encompass a certain degree of error, as do any physical measurements.

Unacceptable. A treatment/control site pair was placed in this category if it neither satisfied the criteria for acceptability nor qualified for conditional acceptability.

APPENDIX I

ELECTROMAGNETIC EXPOSURE SETUP PROTOCOLS FOR SOIL AMOEBA STUDIES

ELECTROMAGNETIC EXPOSURE SETUP PROTOCOLS FOR SOIL AMOEBA STUDIES

This appendix documents the protocol written by IITRI to assist the soil amoeba study investigator in setting up his study sites using the culture chamber exposure hardware fabricated by IITRI. The protocol also provides guidelines for adjusting the control boxes for proper EM exposures in the cells and for measuring the control voltages necessary to determine the cell exposure parameters.

MATCHED ELECTRIC FIELD PROTOCOL

(1) Measure maximum electric field, E, in soil, using 1-meter probe.

(2) Multiply electric field value by 0.15 to determine the minimum required drive voltage, V_{DR} (min).

$$V_{DR}\ (\text{min}) = E \times 0.15\ (\text{volts})$$

(3) Locate collector electrodes in line with the maximum electric field in the earth, and spaced far enough apart to generate a voltage across a 2000-ohm resistor that is greater than or equal to V_{DR} (min) (see Figure I-1).

(4) Measure and record electrode spacing and the open circuit (no load) electrode voltage, V_{OC}.

(5) Connect the test cell and control box to the electrodes (see Figure I-2). While monitoring the test cell voltage, V_{CL}, adjust the variable resistor so that V_{CL} is equal to the value given by the following formula:

$$V_{CL} = E \times 0.113\ (\text{volts})$$

(6) With the cell voltage set, measure and record the voltage across the 100-ohm series resistor, V_R. This allows calculation of the cell current and current density.

(7) Measure and record the electrode voltage, V_{DR}, with the test cell and monitoring box connected and adjusted as per step 5, above.

MATCHED CURRENT DENSITY PROTOCOL

(1) Measure maximum electric field, E, in soil, using 1-meter probe.

(2) Locate collector electrodes in line with maximum electric field, with a separation of 1 meter.

(3) Measure exact electrode spacing and open circuit (no load) electrode voltage, V_{OC}. Measured voltage should be within a few percent of that measured in step 1. If not, correct electrode spacing as appropriate.

(4) Connect current-limiting control box (see Figure I-3) to electrodes. Place the current limit select switch to the 2.5-megohm position (2.5 MΩ).

(5) Measure and record the voltages across the test cell, V_{CL}, the resistor, V_R, and the electrodes, V_{DR}, using the test point jacks (see Figure I-3 for test point numbering).

The voltages across the resistor and across the electrodes should be close in value to V_{OC} from step 3.

$$V_R \approx V_{DR} \approx V_{OC}$$

The voltage across the test cell will be much lower, and can be estimated as:

$$V_{CL} \approx 0.6 \times 10^{-3} \times V_{OC} \text{ (volts).}$$

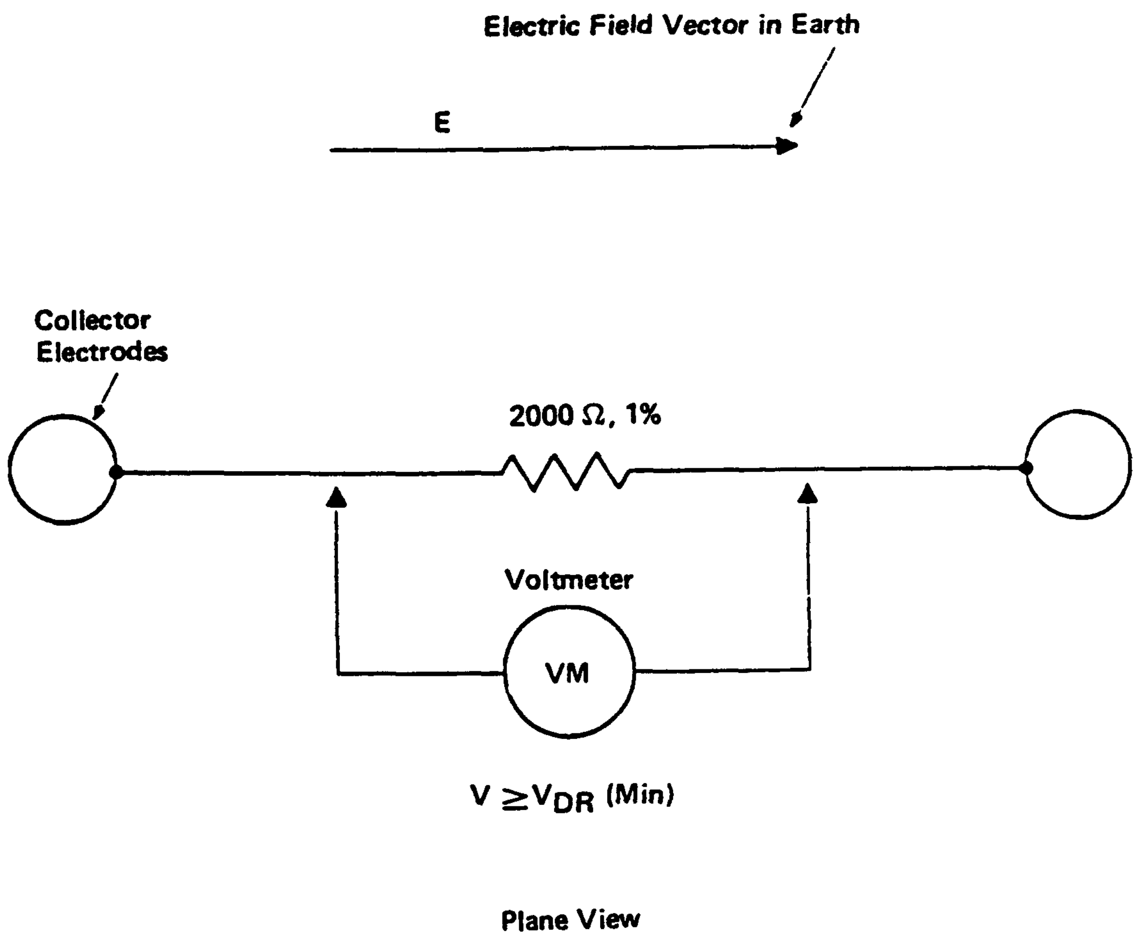
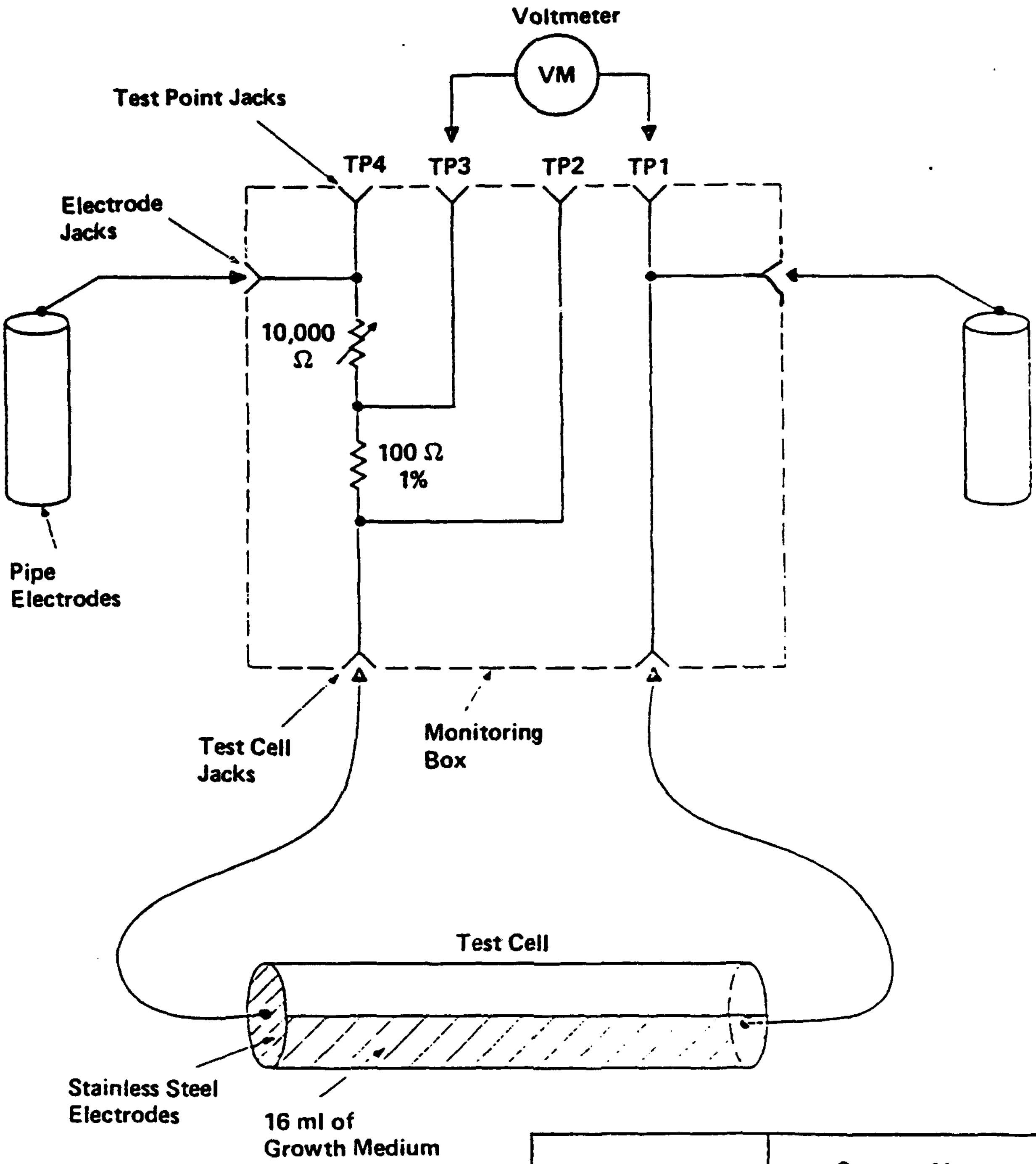


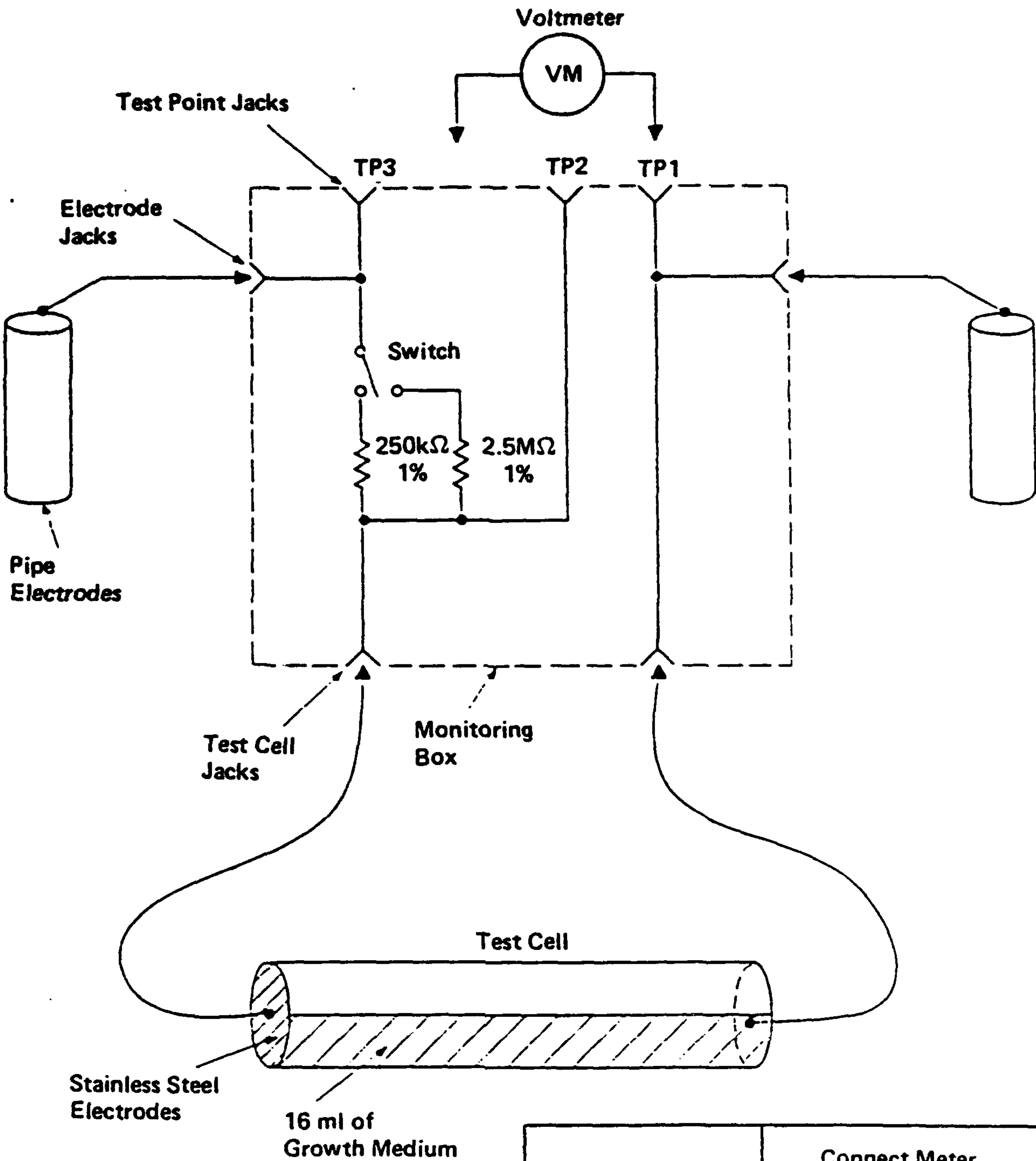
FIGURE I-1. DETERMINATION OF DRIVE VOLTAGE FOR THE SOIL AMOEBA STUDIES MATCHED ELECTRIC FIELD PROTOCOL

60297/790



To Measure	Connect Meter Across
V_{CL}	TP1 – TP2
V_R	TP2 – TP3
V_{DR}	TP1 – TP4

FIGURE I-2. CONTROL BOX CONNECTIONS FOR MATCHED ELECTRIC FIELD CHAMBERS.



To Measure	Connect Meter Across
V_{CL}	TP1 – TP2
V_R	TP2 – TP3
V_{DR}	TP1 – TP3

FIGURE I-3. CONTROL BOX CONNECTIONS FOR MATCHED CURRENT DENSITY CHAMBERS.

APPENDIX J

SUMMARY OF OPERATION, NRTF-REPUBLIC

SUMMARY OF OPERATION, NRTF-REPUBLIC

The operations of the NRTF-Republic during 1986-1991 have been summarized in response to requests from investigators for information on operating schedules. The summary is partitioned according to antenna configuration, modulation, frequency, and antenna current. Separate tables exist for each antenna configuration for each year. Tables J-1, J-2, and J-3 show the number of hours of operation per month in 1986 for the NS, NEW, and SEW antenna or antenna element. Tables J-4 through J-7 show the number of hours of operation per month in 1987 and 1988 for the NS and EW antennas. Tables J-8 through J-16 show the number of hours of operation per month in 1989, 1990, and 1991 for the NS, EW, and both (B) antennas. These tables provide monthly and annual breakdowns of the operation of the NRTF-Republic by antenna current, frequency, and signal type. Subtotals within each column denote the hours of modulated and unmodulated signal operation. The bottom row of the tables gives an estimate of the number of on/off cycles of the antenna or element on a monthly and annual basis. An on/off cycle is defined as one power up and one power down of an antenna or element.

Throughout 1986, 1987, 1988, and early 1989, the NRTF-Republic operated primarily to conduct system testing and to take measurements of coupled interference on public utilities. In this operating mode, the antenna elements were cycled on and off as needed to facilitate measurements. In 1986, the cycling of the antennas was dictated primarily by measurement crews via radio communication with the transmitting site. As testing efforts grew in 1987, 1988, and early 1989, the antennas were automatically cycled on and off during testing hours on a 15-minute rotational cycle. The cycle was divided into three 5-minute periods of NS antenna operation, EW antenna operation, and no antenna operation, as described in Section 4.4.2 of this report. This procedure permitted several measurement crews to perform measurements simultaneously.

The NRTF-Republic operating logs routinely provided to IITRI for this period typically showed only the daily beginning and ending times of the 15-minute rotational cycle operation periods. Separate entries were not included for each change of antenna elements during the cycling, nor were deviations from the cycle necessarily accounted for. Thus, the exact number of on/off cycles and duration of operating time for each antenna element could not be determined exactly, but were estimated by the procedure described below for 1987, 1988, and early 1989.

The total number of on/off cycles for each element was calculated by multiplying the number of hours between the start and finish of the rotational cycling of the antenna elements by 4, since each element had one on/off cycle every 15 minutes. The monthly operation time for each antenna during rotational cycling of the NRTF-Republic was calculated by multiplying the total time period of the rotational cycling

by one-third. This is because each element was estimated to have a 33% duty cycle during cyclic operation periods.

Calculation of operating times and the number of on/off cycles during periods when rotational cycling was not employed (1986, late 1989, 1990, and 1991) were made by directly summming operating time periods and antenna power-up events from the NRTF-Republic operating logs. The estimates of NRTF-Republic operating time and on/off cycles calculated by the above procedures were judged adequate for general use. However, IITRI can obtain exact, minute-by-minute log data for the NRTF-Republic for specific periods as required by the researchers.

TABLE J-1. 1986 OPERATIONS SUMMARY, NRTF-REPUBLIC: NORTH-SOUTH ANTENNA ONLY
(Hours of Operation)

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
Mode: Modulated Signal[a]													
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mode: Unmodulated Signal													
76 (4 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	24.43	16.74	10.71	11.49	0.00	0.00	63.37
76 (6 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.11
76 (10 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotals	0.00	0.00	0.00	0.00	0.00	0.00	24.43	16.74	10.82	11.49	0.00	0.00	63.48
Other[b]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.07
Totals	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**24.43**	**16.74**	**10.89**	**11.49**	**0.00**	**0.00**	**63.55**
Antenna On/Off Cycles	0	0	0	0	0	0	145	23	31	60	0	0	259

[a]Frequencies listed refer to the center frequency of modulation.

[b]Denotes short periods of time at other frequencies or undesignated operation.

TABLE J-2. 1986 OPERATIONS SUMMARY, NRTF-REPUBLIC: NORTHERN EAST-WEST ANTENNA ELEMENT ONLY (Hours of Operation)

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
Mode: Modulated Signal[a]													
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mode: Unmodulated Signal													
76 (4 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.11	0.00	0.00	0.00	0.16
76 (6 Amps)	0.00	0.00	0.00	0.00	0.00	18.87	13.80	0.36	2.46	9.15	0.00	0.00	44.64
76 (10 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotals	0.00	0.00	0.00	0.00	0.00	18.87	13.80	0.41	2.57	9.15	0.00	0.00	44.80
Other[b]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.06
Totals	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**18.87**	**13.80**	**0.41**	**2.63**	**9.15**	**0.00**	**0.00**	**44.86**
Antenna On/Off Cycles	0	0	0	0	0	55	10	2	26	83	0	0	176

[a]Frequencies listed refer to the center frequency of modulation.

[b]Denotes short periods of time at other frequencies or undesignated operation.

TABLE J-3. 1986 OPERATIONS SUMMARY, NRTF-REPUBLIC: SOUTHERN EAST-WEST ANTENNA ELEMENT ONLY (Hours of Operation)

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
						Mode: Modulated Signal[a]							
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
						Mode: Unmodulated Signal							
76 (4 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.01	0.00	0.00	0.00	0.05
76 (6 Amps)	0.00	0.00	0.00	0.00	0.00	11.72	0.00	0.00	5.26	5.76	0.00	0.00	22.74
76 (10 Amps)	0.00	0.00	3.87	18.64	6.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	28.66
Subtotals	0.00	0.00	3.87	18.64	6.15	11.72	0.00	0.04	5.27	5.76	0.00	0.00	51.45
Other[b]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.03
Totals	**0.00**	**0.00**	**3.87**	**18.64**	**6.15**	**11.72**	**0.00**	**0.04**	**5.30**	**5.76**	**0.00**	**0.00**	**51.48**
Antenna On/Off Cycles	0	0	27	39	5	6	0	2	30	78	0	0	187

[a]Frequencies listed refer to the center frequency of modulation.

[b]Denotes short periods of time at other frequencies or undesignated operation.

TABLE J-4. 1987 OPERATIONS SUMMARY, NRTF-REPUBLIC: NORTH-SOUTH ANTENNA ONLY
(Hours of Operation)

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
						Mode: Modulated Signal[a]							
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
						Mode: Unmodulated Signal							
76 (15 Amps)	0.00	0.00	0.00	0.00	0.00	44.40	27.59	32.40	38.86	33.08	21.79	0.00	198.12
Subtotals	0.00	0.00	0.00	0.00	0.00	44.40	27.59	32.40	38.86	33.08	21.79	0.00	198.12
Other[b]	0.00	0.00	0.00	0.42	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.84
Totals	**0.00**	**0.00**	**0.00**	**0.42**	**0.42**	**44.40**	**27.59**	**32.40**	**38.86**	**33.08**	**21.79**	**0.00**	**198.96**
Antenna On/Off Cycles	0	0	0	1	1	533	331	389	466	397	262	0	2380

[a]Frequency listed refers to the center frequency of operation.

[b]Denotes small periods of time at other currents or undesignated operation.

TABLE J-5. 1987 OPERATIONS SUMMARY, NRTF-REPUBLIC: EAST-WEST ANTENNA ONLY
(Hours of Operation)

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
Mode: Modulated Signal[a]													
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mode: Unmodulated Signal													
76 (15 Amps)	0.00	0.00	0.00	0.00	0.00	43.95	27.81	32.39	38.61	33.94	21.90	0.00	198.60
Subtotals	0.00	0.00	0.00	0.00	0.00	43.95	27.81	32.39	38.61	33.94	21.90	0.00	198.60
Other[b]	0.00	0.00	0.00	0.25	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67
Totals	0.00	0.00	0.00	0.25	0.42	43.95	27.81	32.39	38.61	33.94	21.90	0.00	199.27
Antenna On/Off Cycles	0	0	0	1	1	527	334	389	463	407	263	0	2385

[a]Frequency listed refers to the center frequency of operation.

[b]Denotes small periods of time at other currents or undesignated operation.

TABLE J-6. 1988 OPERATIONS SUMMARY, NRTF-REPUBLIC: NORTH-SOUTH ANTENNA ONLY
(Hours of Operation)

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
						Mode: Modulated Signal[a]							
76 (75 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	3.27	0.14	0.00	0.00	0.00	0.00	3.41
Subtotal	0.00	0.00	0.00	0.00	0.00	0.00	3.27	0.14	0.00	0.00	0.00	0.00	3.41
						Mode: Unmodulated Signal							
76 (15 Amps)	27.13	26.36	27.14	34.14	41.23	43.27	0.19	0.00	0.00	0.00	0.00	0.00	199.46
76 (75 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	27.62	59.53	34.24	52.86	12.67	23.76	210.68
44 (75 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	1.27	0.00	26.16	2.61	31.20	15.68	76.92
Subtotals	27.13	26.36	27.14	34.14	41.23	43.27	29.08	59.53	60.40	55.47	43.87	39.44	487.06
Other[b]	0.00	0.00	0.00	0.00	0.00	0.00	8.09	0.00	0.00	0.00	0.00	0.00	8.09
Totals	**27.13**	**26.36**	**27.14**	**34.14**	**41.23**	**43.27**	**40.44**	**59.67**	**60.40**	**55.47**	**43.87**	**39.44**	**498.56**
Antenna On/Off Cycles	326	316	326	410	495	519	485	714	725	666	526	473	5981

[a]Frequency listed refers to the center frequency of operation.

[b]Denotes small periods of time at other currents or undesignated operation.

TABLE J-7. 1988 OPERATIONS SUMMARY, NRTF-REPUBLIC: EAST-WEST ANTENNA ONLY (Hours of Operation)

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
Mode: Modulated Signal[a]													
76 (15 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	3.32	0.14	0.00	0.00	0.00	0.00	3.46
Subtotal	0.00	0.00	0.00	0.00	0.00	0.00	3.32	0.14	0.00	0.00	0.00	0.00	3.46
Mode: Unmodulated Signal													
76 (15 Amps)	27.14	30.95	31.48	34.34	41.33	43.13	0.22	0.00	0.00	0.00	0.00	0.00	208.59
76 (75 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	31.10	68.99	34.71	56.05	12.67	23.76	227.28
44 (75 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	1.06	0.00	26.38	2.52	31.29	15.58	76.83
Subtotals	27.14	30.95	31.48	34.34	41.33	43.13	32.38	68.99	61.09	58.57	43.96	39.34	512.70
Other[b]	0.00	0.00	0.00	0.25	0.42	0.00	7.20	0.00	0.00	0.00	0.00	0.00	7.20
Totals	**27.14**	**30.95**	**31.48**	**34.34**	**41.33**	**43.13**	**42.90**	**69.13**	**61.09**	**58.57**	**43.96**	**39.34**	**523.36**
Antenna On/Off Cycles	326	371	378	412	496	518	526	827	733	703	527	472	6289

[a]Frequency listed refers to the center frequency of operation.

[b]Denotes small periods of time at other currents or undesignated operation.

TABLE J-8. 1989 OPERATIONS SUMMARY, NRTF-REPUBLIC: NORTH-SOUTH ANTENNA ONLY
(Hours of Operation)

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
Mode: Modulated Signal[b]													
44	0.00	0.00	0.00	0.00	0.19	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.20
76	0.00	0.00	0.00	0.00	6.91	0.00	0.00	0.05	0.85	0.00	19.00	0.00	26.81
78	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32
Subtotals	0.00	0.00	0.00	0.00	7.42	0.00	0.01	0.05	0.85	0.00	19.00	0.00	27.33
Mode: Unmodulated Signal													
44	8.02	22.24	12.28	0.86	0.43	0.60	4.51	14.16	0.00	0.00	0.15	0.00	63.25
72	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.48	0.00	0.00	0.00	0.00	0.75
76	37.53	21.16	8.19	0.30	3.82	0.42	9.19	25.30	3.55	0.00	0.00	0.00	109.46
80	0.00	0.00	0.00	0.00	0.00	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.38
Subtotals	45.55	43.40	20.47	1.16	4.25	1.67	13.70	39.94	3.55	0.00	0.15	0.00	173.84
Other[c]	0.00	0.00	0.00	0.00	0.40	1.24	0.35	0.02	0.00	0.00	0.00	0.00	2.01
Totals	**45.55**	**43.40**	**20.47**	**1.16**	**12.07**	**2.91**	**14.06**	**40.01**	**4.40**	**0.00**	**19.15**	**0.00**	**203.18**
Antenna On/Off Cycles	547	521	245	2	30	73	9	24	97	1	7	0	1556

[a]75 ampere antenna current used in Jan-Mar; 150 ampere antenna current used in Apr-Dec.

[b]Frequency listed refers to the center frequency of operation.

[c]Denotes small periods of time at other currents or undesignated operation.

TABLE J-9. 1989 OPERATIONS SUMMARY, NRTF-REPUBLIC: EAST-WEST ANTENNA ONLY (Hours of Operation)

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
							Mode: Modulated Signal[b]						
44	0.00	0.00	0.00	0.00	0.11	0.20	0.29	0.00	0.00	0.00	0.00	0.00	0.60
76	0.00	0.00	0.00	0.00	1.85	0.13	0.48	0.00	0.34	23.70	0.00	0.00	26.50
78	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13
Subtotals	0.00	0.00	0.00	0.00	2.09	0.33	0.77	0.00	0.34	23.70	0.00	0.00	27.23
							Mode: Unmodulated Signal						
44	8.02	22.24	12.53	0.00	0.60	0.94	5.2	11.78	0.29	0.00	0.00	0.00	61.60
72	0.00	0.00	0.00	0.00	0.00	0.82	0.52	0.00	0.00	0.00	0.00	0.00	1.34
76	37.56	21.16	8.11	2.65	4.78	1.57	9.22	17.83	13.68	0.00	0.00	0.00	116.56
80	0.00	0.00	0.00	0.00	0.00	0.59	0.85	0.00	0.00	0.00	0.00	0.00	1.44
Subtotals	45.58	43.40	20.64	2.65	5.38	3.92	15.79	29.61	13.97	0.00	0.00	0.00	180.94
Other[c]	0.00	0.00	0.00	0.00	1.00	0.99	2.16	0.00	0.00	0.00	0.00	0.00	4.15
Totals	**45.58**	**43.40**	**20.64**	**2.65**	**7.47**	**4.25**	**16.56**	**29.61**	**14.31**	**23.70**	**0.00**	**0.00**	**212.32**
Antenna On/Off Cycles	548	521	246	1	32	70	57	17	70	2	13	1	1578

[a]75 ampere antenna current used in Jan-Mar; 150 ampere antenna current used in Apr-Dec.

[b]Frequency listed refers to the center frequency of operation.

[c]Denotes small periods of time at other currents or undesignated operation.

TABLE J-10. 1989 OPERATIONS SUMMARY, NRTF-REPUBLIC: NORTH-SOUTH AND EAST-WEST ANTENNAS SIMULTANEOUSLY (Hours of Operation)

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
Mode: Modulated Signal[b]													
44	0.00	0.00	0.00	0.00	23.99	26.03	69.78	51.97	0.00	0.36	0.00	0.00	172.13
76	0.00	0.00	0.00	0.00	56.09	0.84	96.42	229.01	345.51	679.61	690.11	743.38	2840.97
78	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.35
Subtotals	0.00	0.00	0.00	0.00	80.11	26.87	166.2	280.98	345.51	680.29	690.11	743.38	3013.45
Mode: Unmodulated Signal													
44	0.35	1.12	0.61	4.30	119.33	76.04	82.41	49.14	7.18	0.00	0.47	0.00	340.95
72	0.00	0.00	0.00	0.00	0.42	1.64	0.46	0.02	0.07	0.00	0.00	0.00	2.61
76	1.04	1.84	7.37	2.95	125.65	389.56	354.51	121.39	164.37	9.70	4.97	0.00	1183.35
80	0.00	0.00	0.00	0.00	6.05	24.75	0.00	46.03	0.09	0.00	0.00	0.00	76.92
Subtotals	1.39	2.96	7.98	7.25	251.45	491.99	437.38	216.58	171.71	9.70	5.44	0.00	1603.83
Other[c]	0.00	0.00	0.00	0.00	1.30	6.90	4.09	1.69	0.00	29.69	4.68	0.00	48.35
Totals	**1.39**	**2.96**	**7.98**	**7.25**	**332.86**	**525.76**	**607.67**	**499.25**	**517.22**	**719.68**	**700.23**	**743.38**	**4665.63**
Antenna On/Off Cycles	24	24	16	2	73	125	110	88	145	80	68	55	810

[a]75 ampere antenna current used in Jan-Mar; 150 ampere antenna current used in Apr-Dec.

[b]Frequency listed refers to the center frequency of operation.

[c]Denotes small periods of time at other currents or undesignated operation.

TABLE J-11. 1990 OPERATIONS SUMMARY, NRTF-REPUBLIC: NORTH-SOUTH ANTENNA ONLY
(Hours of Operation)

Frequency, Hz	Month Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Totals
						Mode: Modulated Signal[b]							
76	0.43	0.10	15.98	5.20	2.15	0.55	5.08	105.23	2.78	19.78	0.00	0.03	157.31
Subtotals	0.43	0.10	15.98	5.20	2.15	0.55	5.08	105.23	2.78	19.78	0.00	0.03	157.31
						Mode: Unmodulated Signal							
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other[c]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Totals	**0.43**	**0.10**	**15.98**	**5.20**	**2.15**	**0.55**	**5.08**	**105.23**	**2.78**	**19.78**	**0.00**	**0.03**	**157.31**
Antenna On/Off Cycles	4	1	3	4	2	1	2	6	5	1	0	1	30

[a]150 ampere antenna current used throughout 1990.

[b]Frequency listed refers to the center frequency of operation.

[c]Denotes small periods of time at other currents or undesignated operation.

TABLE J-12. 1990 OPERATIONS SUMMARY, NRTF-REPUBLIC: EAST-WEST ANTENNA ONLY (Hours of Operation)

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
						Mode: Modulated Signal[b]							
76	0.00	3.16	20.90	1.42	0.62	0.73	0.07	0.50	8.65	0.00	0.00	0.05	36.10
Subtotals	0.00	3.16	20.90	1.42	0.62	0.73	0.07	0.50	8.65	0.00	0.00	0.05	36.10
						Mode: Unmodulated Signal							
76	0.00	0.00	0.00	115.74	80.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	196.45
80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotals	0.00	0.00	0.00	115.74	80.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	196.45
Other[c]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Totals	**0.00**	**3.16**	**20.90**	**117.16**	**81.33**	**0.73**	**0.07**	**0.50**	**8.65**	**0.00**	**0.00**	**0.05**	**232.55**
Antenna On/Off Cycles	75	14	5	89	73	4	1	0	5	0	0	1	267

[a] 150 ampere antenna current used throughout 1990.

[b] Frequency listed refers to the center frequency of operation.

[c] Denotes small periods of time at other currents or undesignated operation.

TABLE J-13. 1990 OPERATIONS SUMMARY, NRTF-REPUBLIC: NORTH-SOUTH AND EAST-WEST ANTENNAS SIMULTANEOUSLY
(Hours of Operation)

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
						Mode: Modulated Signal[b]							
76	699.75	606.50	636.26	542.87	612.78	684.44	704.67	591.42	659.63	678.11	674.35	702.78	7793.56
Subtotals	699.75	606.50	636.26	542.87	612.78	684.44	704.67	591.42	659.63	678.11	674.35	702.78	7793.56
						Mode: Unmodulated Signal							
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.00	0.00	0.00	0.00	0.45
80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.47	0.00	0.00	0.00	0.00	4.47
Subtotals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.92	0.00	0.00	0.00	0.00	4.92
Other[c]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Totals	**699.75**	**606.50**	**636.26**	**542.87**	**612.78**	**684.44**	**704.67**	**596.34**	**659.63**	**678.11**	**674.35**	**702.78**	**7798.48**
Antenna On/Off Cycles	30	19	18	88	71	41	15	27	13	12	17	33	384

[a]150 ampere antenna current used throughout 1990.

[b]Frequency listed refers to the center frequency of operation.

[c]Denotes small periods of time at other currents or undesignated operation.

TABLE J-14. 1991 OPERATIONS SUMMARY, NRTF-REPUBLIC: NORTH-SOUTH ANTENNA ONLY (Hours of Operation)

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
Mode: Modulated Signal[b]													
76	0.00	0.00	0.02	0.00	557.4	663.43	225.24	16.81	0.02	0.54	1.56	162.45	1627.47
Subtotals	0.00	0.00	0.02	0.00	557.4	663.43	225.24	16.81	0.02	0.54	1.56	162.45	1627.47
Mode: Unmodulated Signal													
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other[c]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.18
Totals	**0.00**	**0.00**	**0.02**	**0.00**	**557.4**	**663.43**	**225.24**	**16.81**	**0.02**	**0.54**	**1.74**	**162.45**	**1627.65**
Antenna On/Off Cycles	2	0	1	0	35	73	30	4	2	4	4	14	169

[a]150 ampere antenna current used throughout 1991.

[b]Frequency listed refers to the center frequency of operation.

[c]Denotes small periods of time at other currents or undesignated operation.

TABLE J-15. 1991 OPERATIONS SUMMARY, NRTF-REPUBLIC: EAST-WEST ANTENNA ONLY
(Hours of Operation)

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
						Mode: Modulated Signal[b]							
76	0.00	0.00	0.00	0.00	0.00	0.00	3.25	2.01	3.95	0.09	0.00	0.00	9.30
Subtotals	0.00	0.00	0.00	0.00	0.00	0.00	3.25	2.01	3.95	0.09	0.00	0.00	9.30
						Mode: Unmodulated Signal							
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other[c]	0.00	0.00	0.00	0.00	0.00	0.00	1.13	0.00	0.00	0.00	0.00	2.00	3.13
Totals	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**4.38**	**2.01**	**3.95**	**0.09**	**0.00**	**2.00**	**12.43**
Antenna On/Off Cycles	0	0	0	0	0	0	10	4	2	9	0	1	26

[a] *150 ampere antenna current used throughout 1991.*

[b] Frequency listed refers to the center frequency of operation.

[c] Denotes small periods of time at other currents or undesignated operation.

TABLE J-16. 1991 OPERATIONS SUMMARY, NRTF-REPUBLIC: NORTH-SOUTH AND EAST-WEST ANTENNAS SIMULTANEOUSLY (Hours of Operation)

Frequency, Hz	Month: Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Totals
						Mode: Modulated Signal[b]							
76	691.89	617.68	732.65	427.16	150.88	0.00	452.80	637.22	668.79	682.45	656.04	466.73	6184.29
Subtotals	691.89	617.68	732.65	427.16	150.88	0.00	452.80	637.22	668.79	682.45	656.04	466.73	6184.29
						Mode: Unmodulated Signal							
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.50
Subtotals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.50
Other[c]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Totals	**691.89**	**617.68**	**732.65**	**427.16**	**150.88**	**0.00**	**452.80**	**637.22**	**668.79**	**682.45**	**656.54**	**466.73**	**6184.79**
Antenna On/Off Cycles	33	18	27	8	1	0	18	62	38	42	25	10	282

[a]*150 ampere antenna current used throughout 1991.*

[b]Frequency listed refers to the center frequency of operation.

[c]Denotes small periods of time at other currents or undesignated operation.